by
G. R. Jessop
G3JP

radio data reference book

AN RSGB PUBLICATION

Third Edition

£1·00
post paid

RADIO DATA REFERENCE BOOK

RADIO DATA

The lists below are given as an aid to the American reader of RSGB books and publications. Both the semiconductors and tubes are plug in equivalents except where indicated by an asterisk. In this case the suggested substitute will work in many, but not necessarily all circuits.

COMMUNICATIONS TECHNOLOGY, INC.
GREENVILLE, N.H. 03048

VOCABULARY

Break	Bandpass filter	HT	High tension or B+
Concentric trimmer	Piston capacitor	LT	Low tension or filament
Durofix	Q-dope	Perspex	Similiar to plexiglass
Dust core	Ferrite core or tuning slug	Rail	Line (e.g., HV rail = HV line)
Earth	Ground	Screen	Shield
Fault finding	Trouble shooting	Stabilized	Regulated
Former	Coil form	Valve	Vacuum tube
Frequency changer	Mixer	VC	Variable capacitor
FSD	Full-scale deflection	VR	Variable resistor or potentiometer
High-slope	Remote-cutoff	Wafer switch	Rotary switch

Semiconductors:

2G401	2N3783*, HEP3*, SK3006*	2G402	2N3783*, HEP3*, SK3006*	AC107	HEP3, SK3004
AF114	2N2089, HEP3, SK3007	AF115	2N2089, HEP3, SK3006	AF117	2N2092, HEP3, SK3007
AF139	HEP3, SK3006	AFZ12	2N3783	BC109	HEP50*
BCZ11	2N2411	BFY51	2N3053*	GET103	HEP3*, SK3004*
GET104	HEP254*, SK3003*	GET572	2N1667*	GET573	2N1669*
GET880	HEP3, SK3004	GM0290	HEP3*, SK3006*	GM0378	2N3783*
OC28	2N1666, HEP230, SK3009	OC29	2N1667, HEP230, SK3009	OC35	2N1668, HEP230, SK3009
OC36	2N1669, SK3009				

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		[illegible]	HEP254, SK3005		
0C71	HEP3, SK3004	0C72	HEP254, SK3003	0C70	HEP3, SK3003
0C81	HEP254	0C83	HEP3	0C76	2N2706, HEP254
0C139	GE-7	0C170	2N3783, 2N3784, HEP3	0C84	HEP3
XA101	HEP254*, SK3005*	XB104	HEP3*, SK3004*	0C171	HEP3, SK3006

Vacuum Tubes:

5B/254M	807W*	9D6	6CQ6	A2521	6CR4	A2599	6CT4	B329	12AU7
B339	12AX7	B719	6AQ8	E180F	6688	EABC80	6AK8	EB34	6H6
EB91	6AL5	EBC90	6AT6	EBC91	6AV6	EC80	6Q4	EC81	6R4
EC84	6AJ4	EC86	6CM4	EC90	6C4	EC91	6AQ4	EC92	6AB4
EC94	6AF4	EC95	6ER5	EC97	6FY5	EC8010	8556	ECC81	12AT7
ECC82	12AU7	ECC83	12AX7	ECC84	6CW7	ECC85	6AQ8	ECC86	6GM8
ECC88	6DJ8	ECC91	6J6	ECC180	6BQ7A	ECC186	12AU7	ECC230	6080
ECF80	6BL8	ECF82	6U8	ECF86	6Hg8	ECH35	6K8	ECH42	6CU7
ECH80	6AN7	ECH81	6AJ8	ECL80	6AB8	ECL82	6BM8	ECL84	6DX8
ECL85	6GV8	ECL86	6GW8	EF37	6J7	EF39	6K7	EF80	6BX6
EF81	6BH5	EF82	6CH6	EF85	6BY7	EF86	6267	EF89	6DA6
EF91	6AM6	EF92	6CQ6	EF93	6BA6	EF94	6AU6	EF95	6AK5
EF96	6AG5	EF183	6EH7	EF184	6EJ7	EF190	6CB6	EK90	6BE6
EL37	6L6	EL81	6CJ6	EL84	6BQ5	EL85	6BN5	EL86	6CW5
EL90	6AQ5	EL91	6AM5	EL180	12BY7	EM81	6DA5	EZ90	6X4
EZ91	6AV4	KT55	50L6	KT66	6L6GC	KT88	6550	QQV02-6	6939
QQV03-10	6360	QQV03-20A	6252	QQV04-15	832A	QQV06-40A	5894	QQV07-40	829B
QV1-150A	4X150A	QV03-12	5763	QV06-20	6146	QY3-65	4-65A	QY3-125	4-125A
TT21	7623	Z719	6BX6	Z729	6267				

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RADIO DATA REFERENCE BOOK

(THIRD EDITION)

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RADIO SOCIETY OF GREAT BRITAIN

35 DOUGHTY STREET, LONDON, WC1N 2AE

First Edition 1962
Second Edition 1967
Third Edition 1972

Printed in England for the
Radio Society of Great Britain, 35 Doughty Street, London, WC1N 2AE
by The Garden City Press Ltd, Letchworth, Hertfordshire SG6 1JS

FOREWORD

AS modern radio and electronic equipment becomes more and more complex, it is necessary for the radio designer, engineer and amateur to have available in convenient form a large amount of essential reference data.

In compiling this book, the aim has been to provide as wide a range of material as possible which if sought by the normal means would involve lengthy research through many volumes. The actual contents are a significantly different and wider cross-section of the available information than that at present contained in other books of this type.

In general the data is presented in the form of curves, tables and charts with only sufficient text to permit its effective use. In adopting this method of presentation it has been assumed that the reader will have sufficient fundamental knowledge for the direct application of the data. Where theoretical information on any subject is required the reader is referred to the RSGB *Radio Communication Handbook* or other appropriate reference book.

It is inevitable that in compiling a reference book of this nature a large and varied number of sources should be consulted. Acknowledgement, therefore, is made to the editors and authors of the many technical journals and text books to which reference has been made.

It is hoped that this book will fill a very real need in radio circles. Any suggestions that readers feel may improve this book will be welcomed by the compiler and every effort will be made to incorporate these in any subsequent edition.

The compiler would like to express his indebtedness to Messrs G. C. Fox, CEng, MIEE, G3AEX; R. F. Stevens, G2BVN, and G. M. C. Stone, CEng, MIEE, G3FZL, all of whom are members of the RSGB Technical Committee, for assistance in compiling data and reading proofs. Particular thanks are also due to Mr H. L. Gibson, CEng, MIEE, G8CGA, for the complete revision of the section on rf power amplifiers, and the improved design method for Pi and LPi couplers which is accurate both for matching valves and semi-conductors to normal loading.

G. R. J.

GENERAL FORMULAE

Bias Resistor

The value of the resistor to be connected in the cathode lead for developing the required bias is—

$$R_k = \frac{E_k}{I_k} \times 1{,}000 \text{ ohms}$$

where E_k = bias voltage required (volts) and I_k = total cathode current (mA)

Capacitance

The capacitance of a parallel-plate capacitor is—

$$C = \frac{0{\cdot}224\ KA}{d} \text{ picofarads}$$

where K = dielectric constant (air = 1·0)
A = area of plate (sq. in.)
d = thickness of dielectric (in.)

If A is expressed in sq. cm. and d in cm.,

$$C = \frac{0{\cdot}0885\ KA}{d} \text{ picofarads}$$

For multi-plate capacitors, multiply by the number of dielectric thicknesses.

Capacitance of a coaxial cylinder—

$$C = \frac{0{\cdot}242}{\log_{10} \frac{r_1}{r_2}} \text{ picofarads per cm. length}$$

$r1$ = radius of outer cylinder, $r2$ = radius of inner cylinder.

Capacitors in Series or Parallel

The effective capacitance of a number of capacitors in *series* is—

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \text{etc.}}$$

For two capacitors only—

$$C = \frac{C_1 \times C_2}{C_1 + C_2}$$

The effective capacitance of a number of capacitors in *parallel* is—

$$C = C_1 + C_2 + C_3 + \text{etc.}$$

Decibels

The Bel is defined as the common logarithm of the ratio of two powers. Normally the decibel (one-tenth of a Bel) is employed as a more convenient unit.

$$\text{Decibels (db)} = 10 \times \log_{10} \frac{P_1}{P_2}$$

where P_1 and P_2 are the two power levels.

If equal impedances are employed:

$$\text{Decibels} = 20 \times \log_{10} \frac{V_1}{V_2} \qquad = 20 \times \log_{10} \frac{I_1}{I_2}$$

where V_1, V_2 are the two voltage levels and I_1, I_2 the two current levels.

db	Power Ratio	Voltage Ratio	db	Power Ratio	Voltage Ratio
1	1·26	1·12	15	31·6	5·62
2	1·58	1·26	20	100	10
3	2·0	1·41	30	1000	31·6
4	2·51	1·58	40	10^4	10^2
5	3·16	1·78	50	10^5	316
6	3·98	2·0	60	10^6	10^3
7	5·01	2·24	70	10^7	3160
8	6·31	2·51	80	10^8	10^4
9	7·94	2·82	90	10^9	31600
10	10	3·16	100	10^{10}	10^5

Figures not given in the table above may be obtained from the table on page 66. If two db figures are added, their corresponding power or voltage ratios must be multiplied together, e.g. 45 db = 40 db + 5 db = 100 × 1·78 = 178 Voltage Ratio.

Dynamic Resistance

In a parallel-tuned circuit at resonance the dynamic resistance is—

$$R_d = \frac{L}{Cr} = Q\omega L = \frac{Q}{\omega C} \text{ ohms}$$

where L = inductance (henries)
C = capacitance (farads)
r = effective series resistance (ohms)
Q = Q-value of coil
$\omega = 2\pi \times$ frequency (hertz)

Frequency—Wavelength—Velocity

The velocity of propagation of a wave is—

$$v = f\lambda \text{ centimetres per second}$$

where f = frequency (hertz)
λ = wavelength (centimetres)

For electromagnetic waves in free space the velocity of propagation v is approximately 3×10^{10} cm./sec., and if f is expressed in kilohertz and λ in metres—

$$f = \frac{300{,}000}{\lambda} \text{ kilohertz} \qquad f = \frac{300}{\lambda} \text{ megahertz}$$

or

$$\lambda = \frac{300{,}000}{f} \text{ metres} \qquad \lambda = \frac{300}{f} \text{ metres}$$

where f is in megahertz

Impedance

The impedance of a circuit comprising inductance, capacitance and resistance in series is—

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

where R = resistance (ohms) L = inductance (henries)
$\omega = 2\pi \times$ frequency (Hz) C = capacitance (farads)

The characteristic impedance Z_0 of a feeder or transmission line depends on its cross-sectional dimensions.

(i) Open-wire line:

$$Z_0 = 276 \log_{10} \frac{2D}{d} \text{ ohms}$$

where $\left.\begin{array}{l} D = \text{centre-to-centre spacing of wires} \\ d = \text{wire diameter} \end{array}\right\}$ expressed in the same units

(ii) Coaxial line:

$$Z_0 = \frac{138}{\sqrt{K}} \log_{10} \frac{d_0}{d_i}$$

(iii) Cut-off frequency of a coaxial cable:

$$F_c(\text{MHz}) = \frac{7520}{d_i + d_o \sqrt{K}}$$

where K = dielectric constant of insulation between the conductors (e.g. 2·3 for polythene, 1·0 for air)
d_i = inside diameter of outer conductor (in.)
d_0 = outside diameter of inner conductor (in.)

Inductance of Single Layer Coils

$$L \text{ (in microhenries)} = \frac{a^2 N^2}{9a + 10\,l} \text{ approximately}$$

If the desired inductance is known, the number of turns required may be determined by the formula:

$$N = \frac{5L}{na^2}\left[1 + \sqrt{\left(1 + \frac{0.36n^2a^3}{L}\right)}\right]$$

where N = number of turns
a = radius of coil in inches
n = number of turns per inch
L = inductance in microhenries (μH)
l = length of coil in inches

Slug Tuning. The variation in inductance obtainable with adjustable slugs depends on the winding length and the size and composition of the core and no universal correction factor can be given. For coils wound on Aladdin type F804 formers and having a winding length of 0·3–0·8 in. a dust-iron core will *increase* the inductance to about twice the air-core value: a brass core will *reduce* the inductance to a minimum of about 0·8 times the air-core value.

Inductances in Series or Parallel

The total effective value of a number of inductances connected in *series* (assuming that there is no mutual coupling) is given by—

$$L = L_1 + L_2 + L_3 + \text{etc.}$$

If they are connected in *parallel*, the total effective value is—

$$L = \frac{1}{\dfrac{1}{L_1} + \dfrac{1}{L_2} + \dfrac{1}{L_3} + \text{etc.}}$$

When there is mutual coupling M, the total effective value of two inductances connected in series is—

$$L = L_1 + L_2 + 2\,M \text{ (windings aiding)}$$
$$\text{or } L = L_1 + L_2 - 2\,M \text{ (windings opposing)}$$

Stabilizer Dropper Resistance

The resistor to be connected in series with a gas-filled voltage stabilizer tube is—

$$R = \frac{E_s - E_r}{I} \times 1{,}000 \text{ ohms}$$

where E_s = unregulated h.t. supply voltage (volts)
E_r = regulated h.t. supply voltage (volts)
I = maximum permissible current in regulator tube (milliamperes)

Ohm's Law

For a unidirectional current of constant magnitude flowing in a metallic conductor—

$$I = \frac{E}{R} \qquad E = I\,R \qquad R = \frac{E}{I}$$

where I = current (amperes)
E = voltage (volts)
R = resistance (ohms)

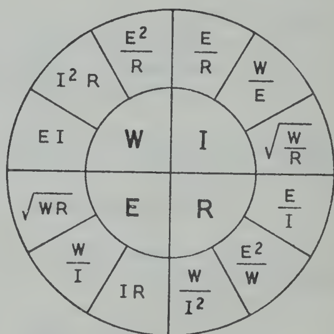


Fig. 1.

Power

In a d.c. circuit the power developed is given by—

$$W = E\,I = \frac{E^2}{R} = I^2\,R \text{ watts}$$

where E = voltage (volts), I = current (amperes), R = resistance (ohms)

Q

The Q value of an inductance is given by—

$$Q = \frac{\omega L}{R}$$

where $\omega = 2\pi \times$ frequency (hertz)
L = inductance (henries)
R = effective series resistance (ohms)

Q Factor of Single Tuned Circuit

$$Q = \frac{f_0}{f_1 - f_2}$$

Where f_0 is the frequency giving maximum response, f_1 and f_2 the frequencies either side of f_0 where the response falls to 0·71 of maximum. All frequency measurements must be expressed in the same units.

Q factors of between 50 and 200 are typical for modern coils.

Reactance

The reactance of an inductor and a capacitor respectively is given by—

$$X_L = \omega L \text{ ohms} \qquad X_c = \frac{1}{\omega C} \text{ ohms}$$

where $\omega = 2\pi \times$ frequency (hertz)
$L =$ inductance (henries)
$C =$ capacitance (farads)

The total reactance of an inductance and a capacitance in series is $X_L - X_C$.

Resistors in Series or Parallel

The effective value of several resistors connected in series is—

$$R = R_1 + R_2 + R_3 + \text{etc.}$$

When several resistors are connected in parallel the effective total resistance is—

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc.}}$$

for two resistors—

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

Resonance

The resonant frequency of a tuned circuit is given by—

$$f = \frac{1}{2\pi\sqrt{LC}} \text{ hertz}$$

where $L =$ inductance (henries)
$C =$ capacitance (farads)

If L is in microhenries (μH) and C is in picofarads (pF = $\mu\mu$F), this formula becomes—

$$f = \frac{10^6}{2\pi\sqrt{LC}} \text{ kilohertz}$$

The basic formula can be rearranged thus:

$$L = \frac{1}{4\pi^2 f^2 C} \text{ henries} \qquad C = \frac{1}{4\pi^2 f^2 L} \text{ farads}$$

Since $2\pi f$ is commonly represented by ω, these expressions can be written as—

$$L = \frac{1}{\omega^2 C} \text{ henries} \qquad C = \frac{1}{\omega^2 L} \text{ farads}$$

Time Constant

For a combination of inductance and resistance in series the time constant (i.e. the time required for the current to reach $1/\epsilon$ or 63 per cent of its final value) is given by—

$$t = \frac{L}{R} \text{ seconds}$$

where L = inductance (henries)
R = resistance (ohms)

For a combination of capacitance and resistance in series the time constant (i.e. the time required for the voltage across the capacitance to reach $1/\epsilon$ or 63 per cent of its final value) is given by—

$t = CR$ seconds where C = capacitance (farads), R = resistance (ohms) (see also page 73)

Toroidal Cores

Ferrite ring cores are suitable for use in pulse transformers, i.f. transformers, d.c.-to-d.c. converter transformers, wideband and impedance matching transformers, filter coils, r.f. coils and delay line coils.

The inductance of a coil wound on a ferrite ring is:

$$L = \left(0{\cdot}0046\, \mu N^2 h \log_{10} \frac{OD}{ID}\right) \mu H$$

where μ = permeability of the core material
N = number of turns
OD = outside diameter of core
ID = inside diameter of core
h = height of core

Magnetising Force

$$H = \frac{0{\cdot}4\, NI}{l} \text{ oersteds}$$

where NI = ampere turns
l = mean magnetic path length

Peak Flux Density

$$B = \frac{E.10^8}{4{\cdot}4\, f.N.A.} \text{ gauss}$$

where E = r.m.s. value of the sinusoidal magnetising voltage in volts
f = frequency
N = number of turns
A = cross-sectional area of the core in cm²

$$u = \frac{B}{H}$$

Transformer Ratios

The ratio of a transformer refers to the ratio of the number of turns in one winding to the number of turns in the other winding. To avoid confusion it is always desirable to state in which sense the ratio is being expressed: e.g. the "primary-to-secondary" ratio n_p/n_s. The turns ratio is related to the impedance ratio thus—

$$\frac{n_p}{n_s} = \sqrt{\frac{Z_p}{Z_s}}$$

where n_p = number of primary turns
n_s = number of secondary turns
Z_p = impedance of primary (ohms)
Z_s = impedance of secondary (ohms)

Valve Characteristics

Amplification Factor (μ) = Valve Anode Resistance (R_a) × Mutual Conductance (g_m), R_a being measured in thousands of ohms and g_m measured in mA per volt.

Alternatively—

$$g_m = \frac{\mu}{R_a} \qquad R_a = \frac{\mu}{g_m}$$

Stage Gain

$$\text{Amplification } (A) = \frac{\mu \times R_1}{R_1 + R_a}$$

where R_1 is the anode load measured in the same units as R_a. If R_1 is small compared with R_a, e.g. television r.f. stages—

$$A = g_m \times R_1 \text{ (approximately)}$$

Cathode Follower

$$\text{Voltage Gain } \frac{V_{out}}{V_{sig}} = \frac{\mu R_k}{r_a + R_k(1 + \mu)}$$

where μ = amplification factor of the valve
r_a = anode impedance
R_k = cathode resistor

The stage gain of a cathode follower will always be less than unity. When μ is large and R_k is large compared with r_a the gain will be near unity.

Stage Gain in Resistance Coupled A.F. Amplifier

$$\text{Medium Frequencies} \quad G_m = \frac{\mu R}{R + R_a}$$

$$\text{High Frequencies} \quad G_h = \frac{G_m}{\sqrt{(1 + \omega^2 C_1^2 r^2)}}$$

$$\text{Low Frequencies} \quad G_l = \frac{G_m}{\sqrt{\left(1 + \dfrac{1}{\omega^2 C_2^2 \rho^2}\right)}}$$

where $R = \dfrac{R_1 R_2}{R_1 + R_2}$

$r = \dfrac{R R_a}{R + R_a}$

$\rho = R_2 + \dfrac{R_1 R_a}{R_1 + R_a}$

μ = amplification factor of valve

$\omega = 2\pi$ frequency
R_1 = anode load resistor
R_2 = grid leak
R_a = valve anode resistance
C_1 = total shunt capacitance
C_2 = coupling capacitor

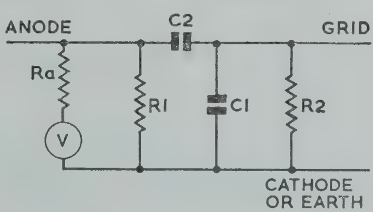


Fig. 2. Input $V = \mu . e_g$

Given C_1 C_2, R_2 and x = fractional response required.

At highest frequency $r = \dfrac{\sqrt{(1 - x^2)}}{\omega C_1 x}$, $R = \dfrac{r R_a}{R_a - r}$, $R_1 = \dfrac{R\ R_2}{R_2 - R}$

At lowest frequency $C_2 = \dfrac{r}{\omega \rho \sqrt{(1 - x^2)}}$

Note the gain will be affected by the cathode and screen bypass capacitors.

Negative Feedback

Voltage Feedback

$$\textit{Gain with feedback} = \frac{A}{1 + Ab}$$

where A is the original gain of the amplifier section over which feedback is applied (including the output transformer if included) and b is the fraction of the output voltage fed back.

$$\textit{Distortion with feedback} = \frac{d}{1 + Ab}\ \textit{approximately}$$

where d is the original distortion of the amplifier.

$$\textit{Effective output Impedance} = \frac{R_a}{1 + \mu b}$$

where μ is the amplification factor of the output valve and R_a its anode resistance.

Current Feedback

This form of feedback may be obtained by omitting the bypass capacitor across the cathode bias resistor. Current feedback results in an increase of effective output impedance and is not recommended for output stages.

Equivalent R.F. Noise Resistance

Saturated Diode	$R_{eq} = \dfrac{0{\cdot}05}{I_a}$ ohms
Space Charge Limited Diode	$R_{eq} = \dfrac{0{\cdot}0333}{I_a}$ ohms
Triode	$R_{eq} = \dfrac{2{\cdot}5}{g_m}$ ohms
Pentode	$R_{eq} = \dfrac{I_a}{I_a + I_{g2}} \left(\dfrac{2{\cdot}5}{g_m} + \dfrac{20 I_{g2}}{g_m^2} \right)$ ohms
Triode Mixer	$R_{eq} = \dfrac{4{\cdot}0}{g_c}$ ohms
Pentode Mixer and Multigrid Mixer	$R_{eq} = \dfrac{I_a}{I_a + I_{g2}} \left(\dfrac{4{\cdot}0}{g_c} + \dfrac{20\ I_{g2}}{g_c^2} \right)$ ohms

I_a and I_{g2} are measured in amps., g_m and g_c are in amps. per volt.

Noise Factor

Noise factor may be calculated from $F = \dfrac{e}{2kT} I_d R_s$

where e electron charge = $1{\cdot}59 \times 10^{-19}$ coulomb

k Boltzman's constant = 1.372×10^{-23} joules per °K

T Temperature of source resistance (°K)

I_d Noise diode anode current (Amps) to double receiver noise output power

R_s Source resistance (Ohms)

At normal temperature (290°K) the above formula becomes

(*a*) as a ratio $F = 20\, I_d\, R_s$

(*b*) in decibels $F = 10_{\log}\,(20\, I_d\, R_s)$

NOISE DIODE CURVES

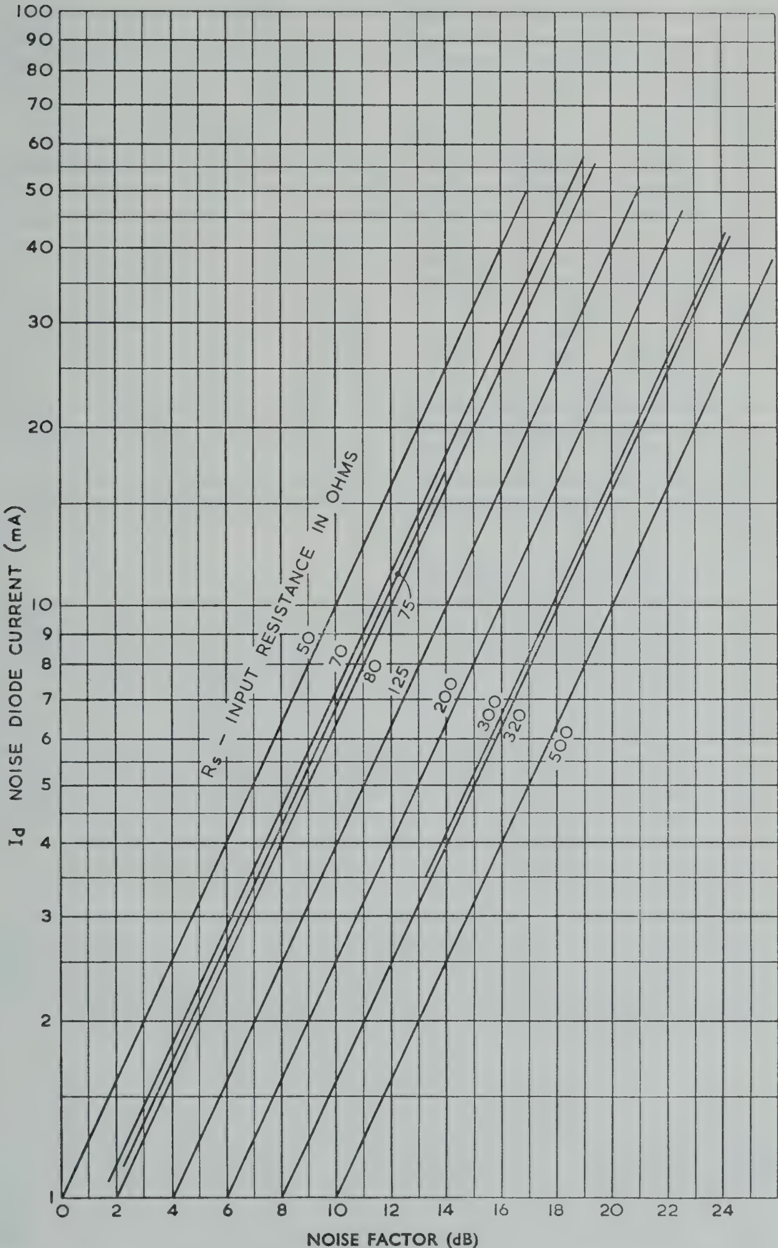


Fig. 3. Noise diode current—noise factor curve for various diode noise generator source resistors

R.F. POWER AMPLIFIERS

In a tuned amplifier the anode and grid voltages are of sine-wave form and in-phase opposition. The anode current does not flow continuously, but in a series of pulses whose duration varies from 40° to more than 180° of each complete cycle of 360°.

The grid current flows for a shorter duration, since this only occurs when the grid is positive relative to the cathode. Figs. 4 and 5 show the basic circuit and phase relationships, respectively. It will be seen that the peak values of anode and grid currents occur when the anode voltage is at a low voltage and the grid voltage is at its maximum positive value. The design methods given here are based on the location of this point on the valve characteristic curves and the translation of the peak values into r.m.s. and mean values, by applying factors derived from a Fourier analysis of sine and sine squared pulses of appropriate angles of flow. This method is very much quicker and only slightly less accurate than the alternative of plotting load lines on constant current characteristics.

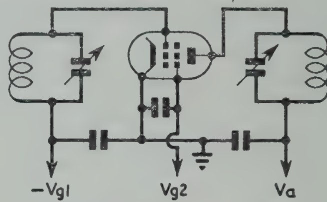


Fig. 4.

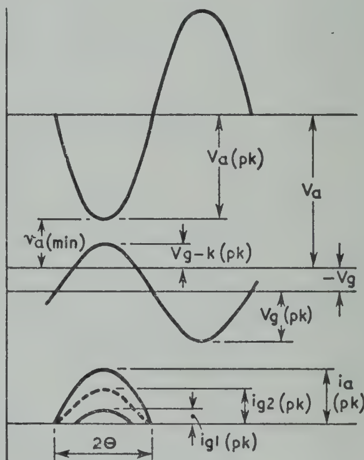


Fig. 5.

The method is best illustrated by a typical example; in this case a transmitting tetrode type TT21 (7623) has been used. The valve has a rated continuous anode dissipation of 37·5 watts. Its characteristics measured at I_a = 140 mA are: mutal conductance (g_m) = 11 mA/V, and inner amplification factor ($\mu_{g1} - _{g2}$) = 8. The relevant valve curves are shown in Figs. 6, 7, 8 and 9.

Class C Telegraphy

A typical angle of anode current flow (2θ) for class C telegraphy is 120°. Smaller angles give increased efficiency, but at the expense of increased peak emission demand, greater driving power and possibly shorter valve life. Larger angles are sometimes used when power output is more important than efficiency.

The design factors required for calculations are F_1, F_2, F_3 and F_4. These can be obtained from the curves in Fig. 10 for an angle of θ of 60°. These are:

$$F_1 = 4{\cdot}6 \qquad F_3 = 2{\cdot}0$$
$$F_2 = 1{\cdot}8 \qquad F_4 = 5{\cdot}8.$$

The design formulae are:

Peak Anode Current $\quad i_{a(pk)} = F_1 \times I_a \quad$ (1)

Peak Anode Voltage $\quad v_{a(pk)} = V_a - v_{a(min)} \quad$ (2)

Power Output $\quad P_{out} = \dfrac{F_2}{2} \times I_a \times v_{a(pk)} \quad$ (3)

Grid Voltage (Triodes) $\quad -V_g = V_a + \left(V_{g-k(pk)} + \dfrac{v_{a\,min}}{\mu}\right)(F_3 - 1) \quad$ (4a)

Grid Voltage (Tetrodes)	$-V_g$	$= \dfrac{V_{g2} \times F_3}{\mu_{(g1-g2)}} + (v_{g1-k(pk)}) \times (F_3 - 1)$	(4b)
Peak Grid Voltage	$v_{g1(pk)}$	$= V_{g1} + (v_{g1-k(pk)})$	(5)

Calculate ratio $\dfrac{V_g}{V_{g(pk)}}$ and from curve in Fig. 11 read F_5 and F_6

Grid Current	I_g	$= \dfrac{i_{g(pk)}}{F_5}$	(6)
Grid Dissipation	p_{g1}	$= \dfrac{I_g \times F_6 \times (V_{g1} - k_{(pk)})}{2}$	(7)
Driving Power	P_{dr}	$= p_{g1} + (V_g \times I_g)$	(8)
Screen Current	I_{g2}	$= \dfrac{i_{g2\,(pk)}}{F_4}$	(9)
Screen Dissipation	P_{g2}	$= V_{g2} \times I_{g2}$	(10)
Output Impedance	R_a	$= \dfrac{v_{a(pk)}}{F_3\ I_a}$	(11)

In order to choose a value for anode input which will exploit the ratings of a chosen valve, an estimated efficiency may be assumed. Alternatively, the input may be fixed by other considerations, such as available power supplies or licence regulations.

A reasonable efficiency for a class C amplifier, at frequencies up to 30 MHz, is 75 per cent. Hence, for the valve chosen, which has an anode dissipation rating of 37·5 watts:

$$\text{Anode input} = \frac{37{\cdot}5}{1 - 0{\cdot}75} = 150 \text{ watts}$$

At an anode voltage of 1000 this corresponds to a d.c. anode current of 150 mA.

From Equation (1) calculate $I_{a(pk)} = 4{\cdot}6 \times 150 = 690$ mA. Next locate the current on the values' Anode Current (I_a) Anode Voltage (V_a) characteristic (Fig. 6) at a low value of anode voltage, just inside the knee of the curve; this corresponds to an anode voltage of 150V and a grid voltage of + 12V.

From Equation (2), calculate $v_{a(pk)} = 1000 - 150 = 850$ volts.

From Equation (3), calculate $P_{out} = \dfrac{1{\cdot}8}{2} \times 0{\cdot}15 \times 850 = 115$ watts.

The anode dissipation is the difference between anode input and power output.

p_a (dissipation) $= 150 - 115 = 35$ watts.

This dissipation is sufficiently close to the maximum rating and can be accepted for the rest of the calculation. If the figure had been greater or considerably lower than the rated maximum, a new design should be made using a different power input, angle of flow or minimum anode voltage $V_{a(min)}$.

The chosen valve is a tetrode and from Equation 4(b) calculate grid voltage:

$$-V_g = \frac{300 \times 2}{8} + 12 \times 1 = -87 \text{ volts.}$$

From Equation (5) calculate $v_{g(pk)} = 87 + 12 = 99$ volts.

Calculate: $\dfrac{V_g}{v_{g(pk)}} = \dfrac{87}{99} = 0{\cdot}88$ and from Fig. 12 read values of F_5 and F_6.

These are 11·7 and 1·975, respectively.

From the Grid Current (I_g), Anode Voltage (V_a) curves of the TT21 (7623) a peak grid current of 32 mA occurs at $V_a = 150$V and $V_{g1} = +12$V.

From Equation (6) calculate $I_g = \dfrac{32}{11{\cdot}7} = 2{\cdot}75$ mA.

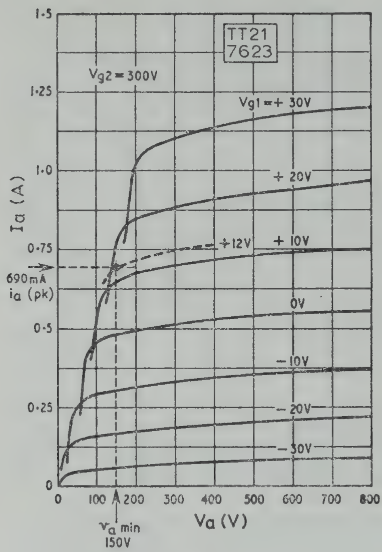


Fig. 6.

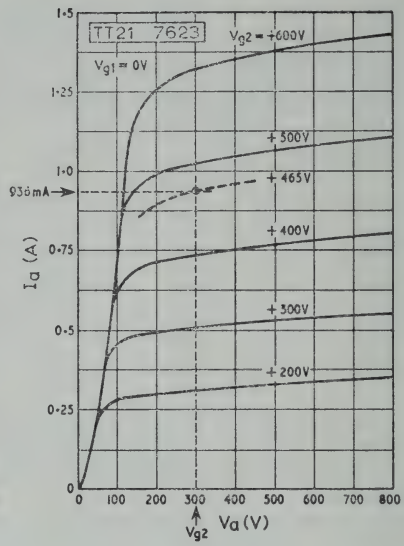


Fig. 7.

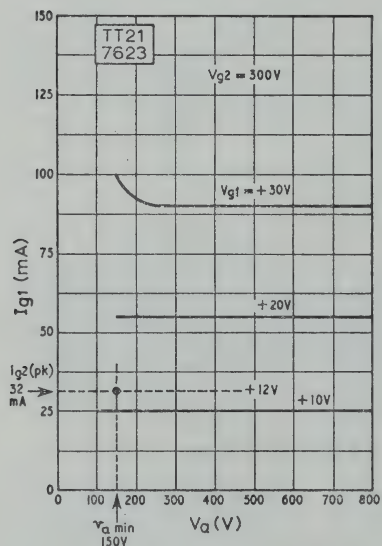


Fig. 8.

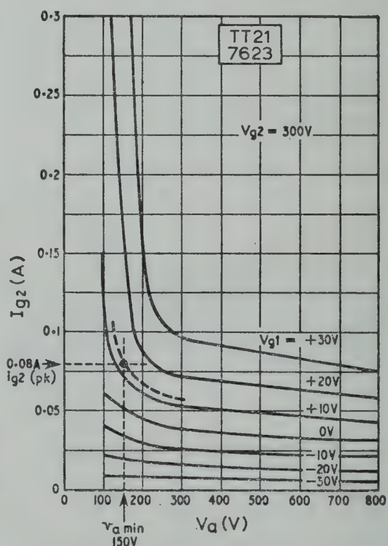


Fig. 9.

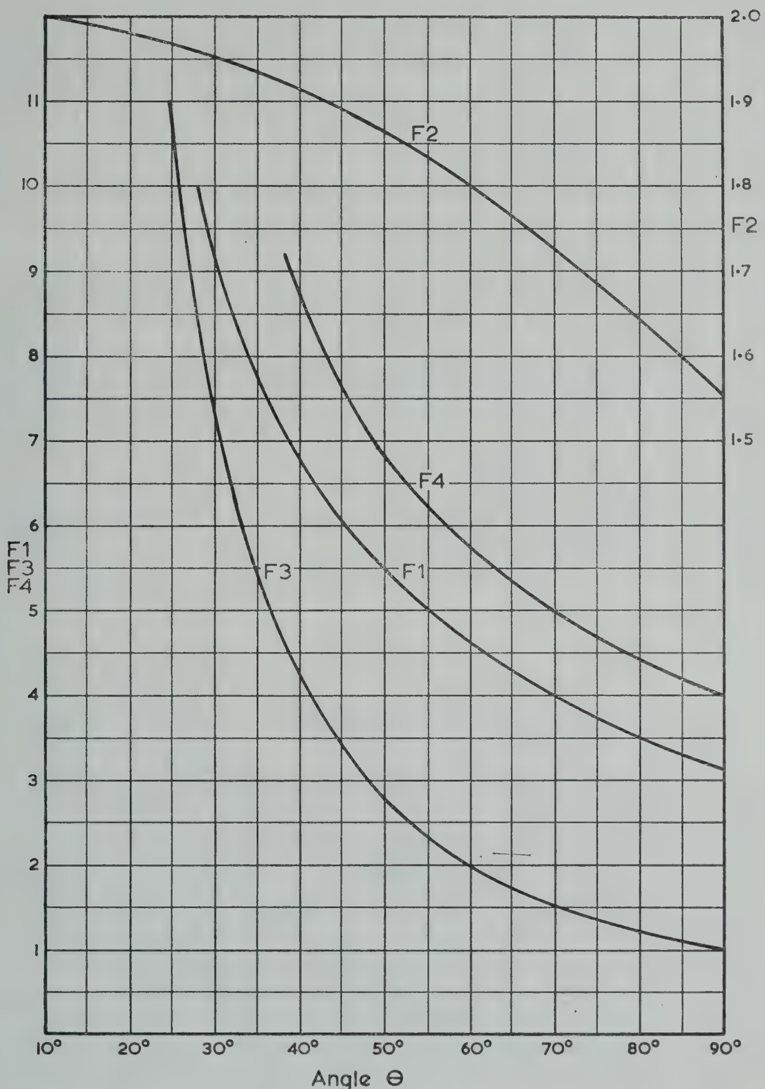

F2
F4
F3
F1
F1
F3
F4
F2
2·0
1·9
1·8
1·7
1·6
1·5
11
10
9
8
7
6
5
4
3
2
1
10°
20°
30°
40°
50°
60°
70°
80°
90°
Angle Θ

Fig. 10.

From Equation (7) calculate $p_{g1} = \dfrac{2 \cdot 75 \times 1 \cdot 975 \times 12}{2} = 32 \cdot 5$ mW.

From Equation (8) calculate $P_{dr} = 32 \cdot 5 + (2 \cdot 75 \times 87) = 273$ mW.

The driver stage should produce considerably more than this minimum power in order to allow for losses in the coupling system.

From the screen grid current (I_{g2}) anode voltage (V_a) curves of the TT21 (7623), a peak screen current of 80 mA occurs at $V_a = 150$V and $V_{g1} = +12$V.

From Equation (9) calculate $I_{g2} = \dfrac{80}{5 \cdot 8} = 13 \cdot 8$ mA.

From Equation (10) calculate $p_{g2} = 300 \times 13 \cdot 8 = 4 \cdot 15$ W.
This dissipation is within the maximum rating of 6 watts and is acceptable.

From Equation (11) calculate $R_a = \dfrac{850}{150 \times 1 \cdot 8} = 3 \cdot 16$ K ohms.

It is now possible to design a Pi coupler to match 3·16 K ohms to the impedance of the load. A suitable value of loaded Q would be 10–12 (see page 27 for Pi and LPi coupler data).

(*The symbol R_a has been used for output impedance in preference to the more usual symbol Z_a. Because it is less confusing in the Pi and LPi coupler design which follows this section.*)

Anode Modulated Amplifiers

Anode modulated amplifiers are designed in a similar manner to that given for class C telegraphy, but checks must be made to ensure that the required conditions at the modulation crest are met.

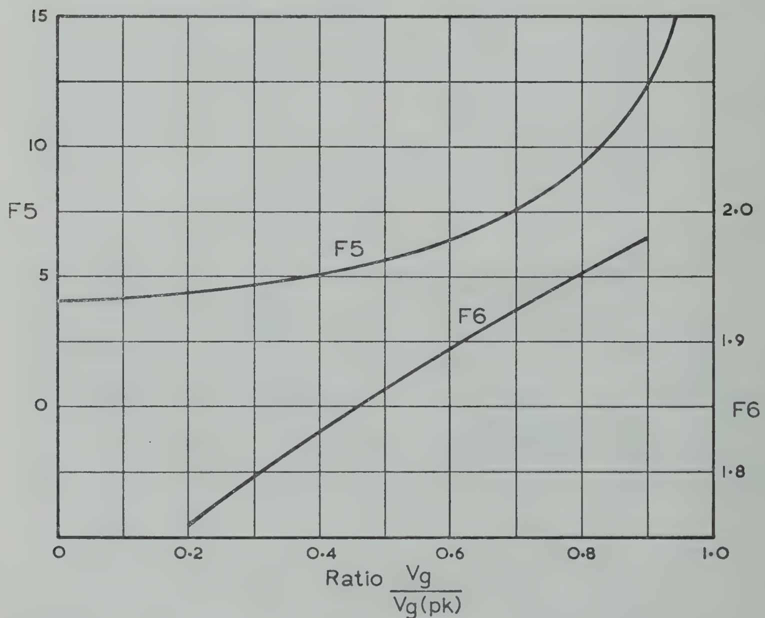


Fig. 11.

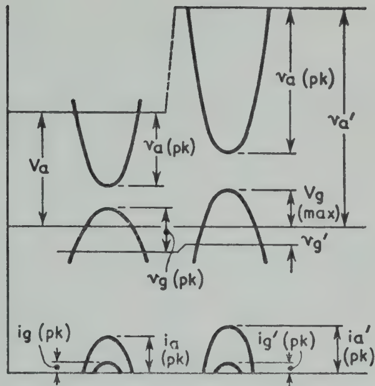


Fig. 12. Phase relationship at the carrier and modulation crest for an anode modulated class C amplifier.

At the modulation crest, the anode and screen voltages will be increased but the bias will be unchanged; hence the angle of anode current flow will increase. Typical values are between 150° and 180°. In making a design, it is best to assume an angle and later check the accuracy of the assumption.

In the following equations, values at the crest of modulation are indicated by ($'$), thus θ' may be between 75° and 90°.

Since the amplifier is assumed to be linear, then:

$$P'_{out} = 4\,P_{out} \qquad (12)$$

$$v'_{a(pk)} = 2\,v_{a(pk)} \qquad (13)$$

Hence $$v'_{a(min)} = 2\,v_{a(min)} \qquad (14)$$

By using Equation (3) rearranged, the anode current at modulation crest can be calculated from—

$$I'_a = \frac{P'_{out} \times 2}{F'_2 \times v_{a(pk)}} \qquad (15)$$

and from Equation (1)

$$i'_{a(pk)} = F'_1 \times I'_a$$

Normally, the positive grid voltage may be assumed to have the same value as calculated at the carrier.

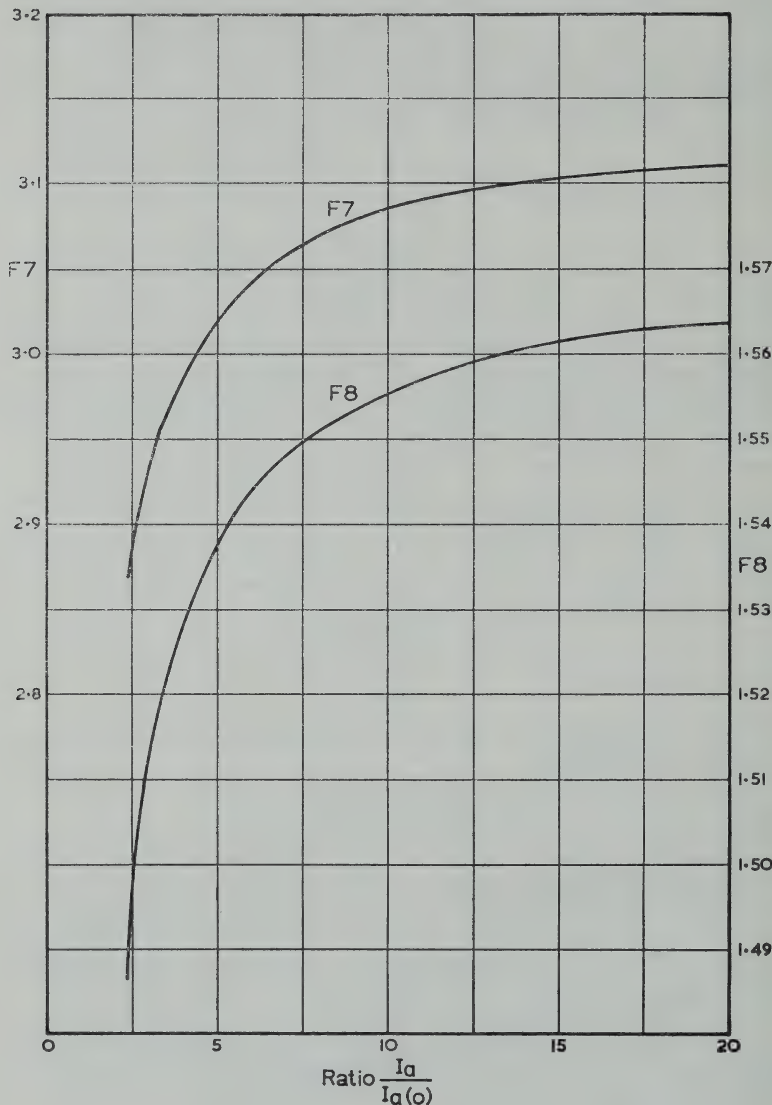
The peak working point corresponding to $i'_{a(pk)}$, $v'_{a(min)}$ and $v_{g1-k(pk)}$ must be located on the anode current (I_a) anode voltage (V_a) curves.

In the case of a tetrode, a value of the screen voltage must be found which satisfies these conditions. In triodes, it may be found that a different (usually greater) value of $v_{g-k(pk)}$ is required to satisfy $i'_{a(pk)}$ and $v'_{a(min)}$.

The grid current at the modulation crest is usually significantly less than at the carrier. By using some grid leak bias, the angle of flow can be increased to 180°, requiring less bias, and hence making available an increased positive grid excursion. An alternative is to supply sufficient modulation to the driver stage to provide the required positive excursion.

For convenience of illustration it will be assumed that the foregoing class C telegraphy design is now to be modulated, but it should be noted that this will not necessarily give a practical result since the anode dissipation rating may be exceeded during modulation.

It is usual practice to quote anode dissipation ratings at carrier (unmodulated) conditions of two-thirds of the maximum valve rating. This is based on the assumption that the average power dissipation will be increased by 1·5 times when modulation is applied. In the valve used for the example, the anode dissipation under modulation must be reduced to $\frac{37{\cdot}5}{1{\cdot}5} = 25$ watts.



3·2
3·1
F7
3·0
2·9
2·8
F7
F8
1·57
1·56
1·55
1·54
F8
1·53
1·52
1·51
1·50
1·49
0
5
10
15
20
Ratio $\frac{I_a}{I_a(o)}$

Fig. 13.

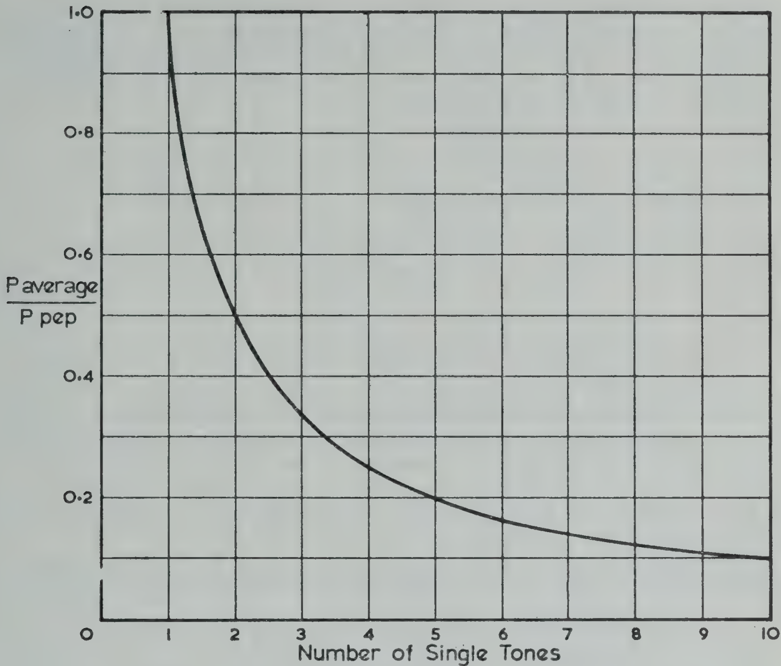

1·0
0·8
0·6
P average
P pep
0·4
0·2
0
1
2
3
4
5
6
7
8
9
10
Number of Single Tones

Fig. 14.

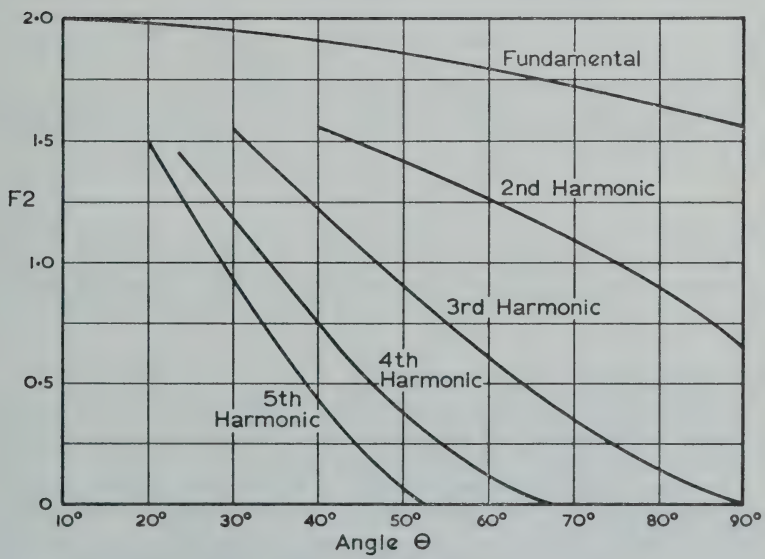

2·0
1·5
F2
1·0
0·5
0
Fundamental
2nd Harmonic
3rd Harmonic
4th
Harmonic
5th
Harmonic
10°
20°
30°
40°
50°
60°
70°
80°
90°
Angle Θ

Fig. 15.

In practice, however, with speech waveforms of relatively high peak to mean ratio, it is satisfactory to use a rather higher dissipation rating. When speech compression is used, or continuous 100 per cent tone modulation is applied, it is important to ensure that the actual anode dissipation under modulation conditions is within the maximum rating.

Returning to the previous design

From Equation (12) calculate $P'_{out} = 4 \times 115 = 460$ watts.
From Equation (13) calculate $v'_{a(pk)} = 2 \times 850 = 1700$ volts.
From Equation (14) calculate $v'_{a(min)} = 2 \times 150 = 300$ volts.
Assuming an angle of anode current flow $(2\theta') = 150°$, then:

$$F'_1 = 3{\cdot}75$$
$$F'_2 = 1{\cdot}69$$
$$F'_3 = 1{\cdot}35.$$

From Equation (15) calculate $I'_a = \dfrac{460 \times 2}{1{\cdot}69 \times 1700} = 320$ mA

From Equation (1) calculate $I'_{a(pk)} = 3{\cdot}75 \times 320 = 1200$ mA.

In order to obtain a peak working point where $i'_a = 1200$ mA at $v'_{a(min)} = 300$V, it is necessary to find the correct value of screen voltage, it being assumed that the grid voltage for the carrier conditions is still available (+ 12V).

From the I_a/V_a curves for the valve at various screen voltages when $V_{g1} = 0$, it is now necessary to predict the screen voltage required to produce $I_{a(pk)} = 1200$ mA at $v'_{a(min)} = 300$V and $v'_{g1} = +12$V.

From the TT21 data, the mutual conductance (g_m) at $I_a = 140$ mA is 11 mA/V, therefore, at $I_a = 1200$ mA, the mutual conductance will increase to:

$$\left(\frac{(I'_{a(pk)})}{I_a}\right)^{1/3} \text{ or } \left(\frac{1200}{140}\right)^{1/3} \text{ which gives 22 mA/V.}$$

From this it follows that the anode current at $V_{g1} = +12$V will be $12 \times 22 = 264$ mA greater than the value at $V_{g1} = 0V$.

The point on the characteristic curve that now has to be found is for $V_{a'} = 300$V, I_a $1200 - 264 = 936$ mA. This corresponds to a screen voltage of 465V.

The screen voltage should therefore be increased by slightly more than 1·5 times when the anode voltage is doubled by modulation. The modulation transformer should be designed to provide this screen modulation point either by a tap on the main winding or by additional winding.

The assumed angle of flow can be checked to see if it is realistic, by calculation of the bias from Equation (4b).

$$-V'_{g1} = \frac{465 \times 1{\cdot}35}{8} + 12 \times 0{\cdot}35 = -82{\cdot}5 \text{ volts}$$

This is close enough to the original value of − 87 volts for a practical design.

In practice, the regulation of the driver source, the change of grid current when the screen voltage is raised and the method of obtaining the bias will modify the available positive grid voltage at the crest, but the calculation gives sufficient guide as a practical starting point.

Class AB and Class B Linear Amplifiers

In class AB and class B linear service, the amplifier is required to handle modulated waveforms without distortion. The amplification of single sideband suppressed carrier signals is the most usual example.

In a class B amplifier, the angle of flow of anode current is close to 180°. An acceptable design can be made using the procedure given for class C telegraphy but with $\theta = 90°$.

In practice, however, such amplifiers are operated with some standing anode current ($I_{a(o)}$) in the absence of a signal, as a means of improving the linearity.

Class AB amplifiers invariably operate at significant standing anode current. Design curves based on angle of flow are therefore inconvenient; curves based on the ratio of mean anode current under driven conditions to standing anode current are more useful.

The curves given in Fig. 13 are suitable. In these, F_7 corresponds to F_1 and F_8 to F_2; from which, under these new conditions:

Peak Anode Current $I_{a(pk)} = F_7 \times I_a$ (16)

Power Output, $P_{out} = \dfrac{F_8}{2} \times I_a \times v_{a(pk)}$ (17)

In a typical class AB amplifier driven to maximum peak envelope power the valve will have an anode efficiency of about 70 per cent. The anode dissipation is a maximum at some value of drive less than the maximum. The anode dissipation at maximum drive must therefore be less than the maximum rating, say 80 per cent.

Taking the same example as used for the class C calculations, the TT21 (7623), an anode dissipation of 30 watts is a suitable starting point. In a final design the values must be chosen so that taking into account the peak to mean ratio of the modulation waveform does not cause excessive anode dissipation.

Taking anode dissipation as 30 watts and anode efficiency of 70 per cent, then:

$$\text{Anode input } P_{in} = \frac{30}{1 - 0{\cdot}7} = 100 \text{ watts.}$$

Decide on the anode voltage; in this case, take $V_a = 1000\text{V}$; then the anode current $I_a = 100$ mA.

Next, it is necessary to decide the zero signal (standing) anode current $I_{a(o)}$; this depends on a compromise between efficiency and intermodulation distortion. Generally a current corresponding to about 66 per cent of the rated anode dissipation is typical from which

$$I_{a(o)} = \frac{2}{3} \times 37{\cdot}5 = 25 \text{ mA.}$$

$$\text{Then } \frac{I_a}{I_{a(o)}} = 4$$

from Fig. 11 $F_5 = 2{\cdot}99$ and $F_6 = 1{\cdot}53$

and from Equation (16) $I_{a(pk)} = 2{\cdot}99 \times 100 = 299$ mA.

Locate this current on the I_a/V_a characteristic curve to find the value of $v_{a(min)}$. To preserve linearity it is important that this point is not in the curved part of the knee characteristic.

From the curve a value of 100 volts is suitable.

Hence:

$$v_{a(pk)} = 1000 - 100 = 900 \text{ volts}$$

and from Equation (17) $P_{out} = \dfrac{1{\cdot}53}{2} \times 0{\cdot}10 \times 900 = 69$ watts

Anode dissipation $p_a = 100 - 69 = 31$ watts.

The calculation of driving power (if any) and anode load impedance follow the same procedure as for class C telegraphy. The bias will, however, be decided by the chosen value of $I_{a(o)}$. The approximate value can be taken from the characteristic curve, but in practice should be set to give the required value of $I_{a(o)}$.

The intermodulation of linear amplifiers is frequently assessed by using a test signal consisting of two or more signals (tones) of equal amplitude. The average power output will decrease as the number of tones is increased in the test signal as shown in Fig. 14.

In the usual case of a two-tone test signal, and assuming ideal linear characteristics, the relation between single and two-tone conditions is:

$$I_{a\,(\text{two tone})} = \frac{2}{\pi} I_{a\,(\text{singletone})}$$

Average input power:

$$P_{\text{in (two tone)}} = V_a \times I_{a\,(\text{two tone})}$$

Average output power:

$$P_{\text{out (two tone)}} = \frac{1}{2} P_{\text{out (single tone)}}$$

Grounded Grid Operation

All the preceding designs are based on the assumption that the signal is applied to the grid and the cathode earthed (grid drive or common cathode connection). Sometimes the signal is applied to the cathode and the grid earthed (grounded grid or cathode drive connection).

This arrangement has the advantage of improved stability usually without neutralizing. It has the disadvantage that much greater driving power is required than that needed for grid drive connection, but some of the driving power is recovered in the output circuit.

The driving power $P_{dr} = (V_g \times I_g) + p_{g1} + \left(\frac{v_{g1(pk)} \times F_2 \times I_a}{2}\right)$

The drive power which appears in the output $= \left(\frac{v_{g1(pk)} \times F_2 \times I_a}{2}\right)$

In the case of a tetrode there is a small additional driving power which is not recovered in the output; this occurs due to the product of peak drive voltage and the fundamental component of the screen current. It is usually sufficiently small to be ignored.

Frequency Multipliers

Frequency multipliers are class C amplifiers in which the anode circuit is tuned to a harmonic of the drive frequency, and may be designed in the same way as a class C amplifier. In general, smaller angles of flow are used, as this tends to increase the harmonic output.

The factor F_2, which in the amplifier design gives the ratio of peak fundamental to d.c. anode current, is replaced by a factor giving the ratio for peak harmonic to d.c. anode current. These factors for harmonics up to the fifth are shown in Fig. 15.

Factors

F_1 and F_7	$\dfrac{\textit{Peak anode current}}{\textit{D.c. anode current}}$	(assuming sine waveform)
F_2 and F_8	$\dfrac{\textit{Peak fundamental component of anode current}}{\textit{D.c. anode current}}$	(assuming sine waveform)
F_3	$\dfrac{1}{1 - \cos\theta}$	
F_4	$\dfrac{\textit{Peak screen current}}{\textit{D.c. screen current}}$	(assuming squared sine waveform)
F_5	$\dfrac{\textit{Peak grid current}}{\textit{D.c. grid current}}$	(assuming squared sine waveform)
F_6	$\dfrac{\textit{Peak fundamental component of grid current}}{\textit{D.c. grid current}}$	(assuming squared sine waveform)

PI AND LPI NETWORK COUPLERS

IMPROVED DESIGN METHODS

The purpose of the pi-network coupler is to present at its input terminals an impedance R_a in order to load a valve or transistor amplifier correctly when the actual load connected to the output terminals of the coupler is a resistance R_2, as shown in Fig. 16.

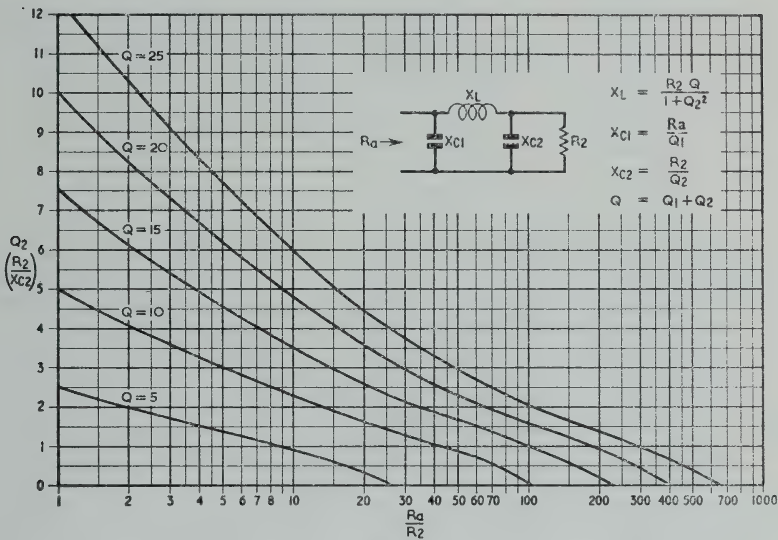


Fig. 16.

Earlier design formulae and curves have assumed X_L to be resonated by X_{C1} and X_{C2} in series, but this assumption is correct only if R_2 is much larger than X_{C2}; this condition is only approached for large ratios of R_a to R_2. For ratios of less than 10, the error becomes quite large and this has become obvious when using the existing formulae for designing transistor matching networks.

To analyse the behaviour of the circuit correctly, it is necessary to convert the parallel components X_{C2}, R_2 into their series equivalent, to add the value of X_L and then reconvert into parallel components. To do this, the following standard conversion formulae are needed; in Fig. 17, the parallel circuit X_p and R_p is equivalent to the series circuit X_s and R_s, if,

$$R_s = \frac{R_p \, . \, X_p^2}{R_p^2 + X_p^2} \qquad \ldots (1)$$

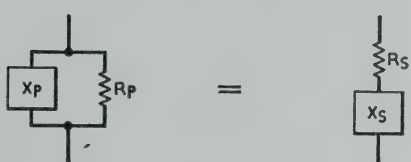


Fig. 17.

REACTANCE CHART
INDUCTANCE

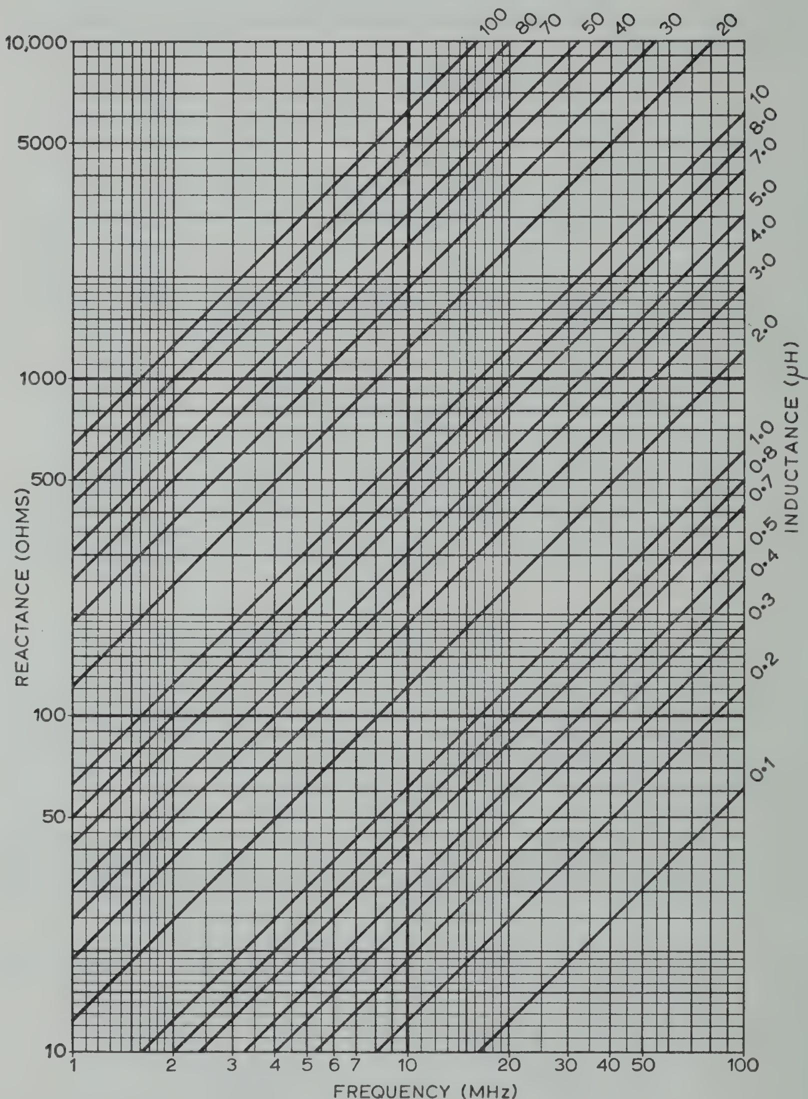


Fig. 18.

$$X_s = \frac{R_p^2 \,.\, X_p}{R_p^2 + X_p^2} \quad \ldots (2)$$

$$R_p = \frac{R_s^2 + X_s^2}{R_s} \quad \ldots (3)$$

$$X_p = \frac{R_s^2 + X_s^2}{X_s} \quad \ldots (4)$$

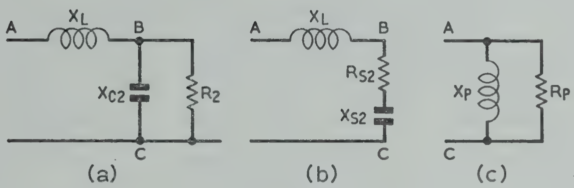


Fig. 19.

The Pi-network omitting X_{c1} is shown in Fig. 19(a).The impedance between B and C consists of X_{c2} and R_2 in parallel and is equivalent to R_{s2} and X_{s2} in series as shown in Fig. 19(b) where,

$$R_{s2} = \frac{R_2 \,.\, X_{c2}^2}{R_2^2 + X_{c2}^2} \quad \ldots (5)$$

$$X_{s2} = \frac{R_2^2 \,.\, X_{c2}}{R_2^2 + X_{c2}^2} = R_{s2} \,.\, \frac{R_2}{X_{c2}} \quad \ldots (6)$$

The coil reactance X_L is in series with these and X_L must be greater than X_{s2} because the total impedance between A and C must be inductive in order to tune with a capacitive X_{c1}. In Fig. 19(b) we have a resistance R_{s2} in series with an inductive reactance $(X_l - X_{s2})$; this combination may be converted to the parallel combination of X_p and R_p shown in Fig. 19(c), where

$$\mathrm{R}_p = \frac{R_{s2}^2 + (X_L - X_{s2})^2}{R_{s2}} \quad \ldots (7)$$

$$X_p = \frac{R_{s2}^2 + (X_L - X_{s2})^2}{X_L - X_{s2}} \quad \ldots (8)$$

The resistive part R_p is clearly our wanted load resistance R_1, while the input capacitance to the Pi coupler X_{c1} must tune out X_p. Hence, numerically $R_1 = R_p$ and $X_{c1} = X_p$.

The loaded Q of the whole circuit is given by

$$Q = \frac{X_L}{R_{s2}} \quad \ldots (9)$$

provided that the impedance of the source is large compared with R_a. Let us designate $\frac{R_2}{X_{c2}} = Q_2$ and $\frac{R_1}{X_{c1}} = Q_1$ remembering that R_1 is not an actual resistor, but the effect of R_2 transformed by the Pi-coupler. Dividing (8) by (7) and rearranging, we have,

$$X_{c1} = \frac{R_a \,.\, R_{s2}}{X_L - X_{s2}}$$

REACTANCE CHART
CAPACITANCE

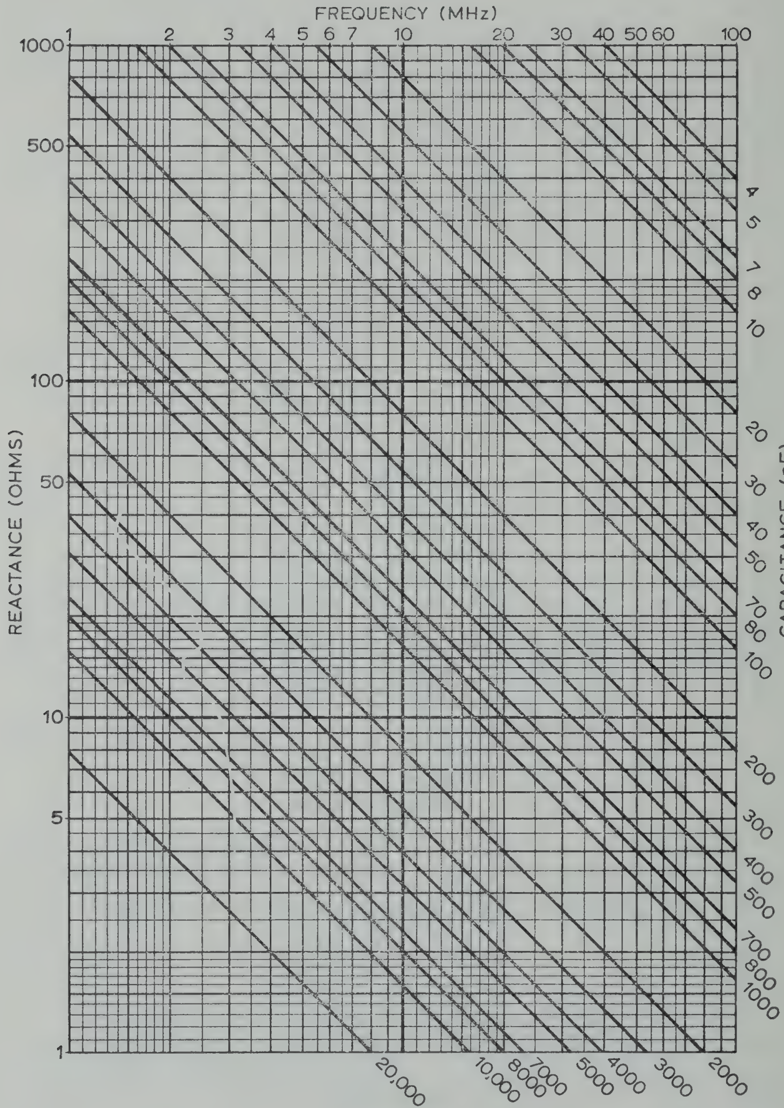


Fig. 20.

Therefore $$\frac{X_{c1}}{R_a} = \frac{R_{s2}}{X_L - X_{s2}}$$

$$\frac{R_a}{X_{c1}} = \frac{X_L}{R_{s2}} - \frac{X_{s2}}{R_{s2}}$$

But $$\frac{X_{s2}}{R_{s2}} = \frac{R_2}{X_{c2}} \text{ (from equation (6)).}$$

therefore $$\frac{X_L}{R_{s2}} = \frac{R_a}{X_{c1}} + \frac{R_2}{X_{c2}}$$

ie $$Q = Q_1 + Q_2. \qquad \ldots (10)$$

Dividing equation (7) by R_{s2}

$$\frac{R_a}{R_{s2}} = 1 + \left(\frac{X_L - X_{s2}}{R_{s2}}\right)^2 = 1 + (Q - Q_2)^2$$

But from equation (5)

$$R_{s2} = \frac{R_2}{1 + \left(\frac{R_2}{X_{c2}}\right)^2} = \frac{R_2}{1 + Q_s^2}$$

therefore $$\frac{R_a}{R_2}(1 + Q_2^2) = 1 + (Q - Q_2)^2$$

$$\frac{R_a}{R_2} = \frac{1 + (Q - Q_2)^2}{1 + Q_2^2} = \frac{1 + Q_1^2}{1 + Q_2^2} \qquad \ldots (11)$$

Now from equation (9)

$$\frac{X_L}{R_2} = \frac{Q \,.\, R_{s2}}{R_2}$$

and since from equation (5)

$$R_{s2} = \frac{R_2}{1 + Q_2^2}$$

therefore $$\frac{X_L}{R_2} = \frac{Q}{1 + Q_2^2} \qquad \ldots (12)$$

We can now prepare design curves for Pi-couplers for any chosen value of Q, by selecting combinations of Q and Q_2 and calculating $\frac{R_a}{R_2}$ from $\frac{1 + Q_1^2}{1 + Q_2^2}$. Thus for $Q = 15$

Q_1	15	14	13	10	7·5	5	2	1	0
Q_2	0	1	2	5	7·5	10	13	14	15
$\frac{R_a}{R_2}$	226	98·5	34	3·88	1	0·257	0·0294	0·0102	0·0044

If $Q_2 \left(\text{i.e. } \frac{R_2}{X_{c2}}\right)$ is plotted against $\frac{R_a}{R_2}$, the appropriate value can be read on the chart for any transformation ratio. It is unnecessary to plot values of $\frac{R_a}{R_2}$ less than 1, since the coupler is reversible.

INDUCTANCE DESIGN CHART

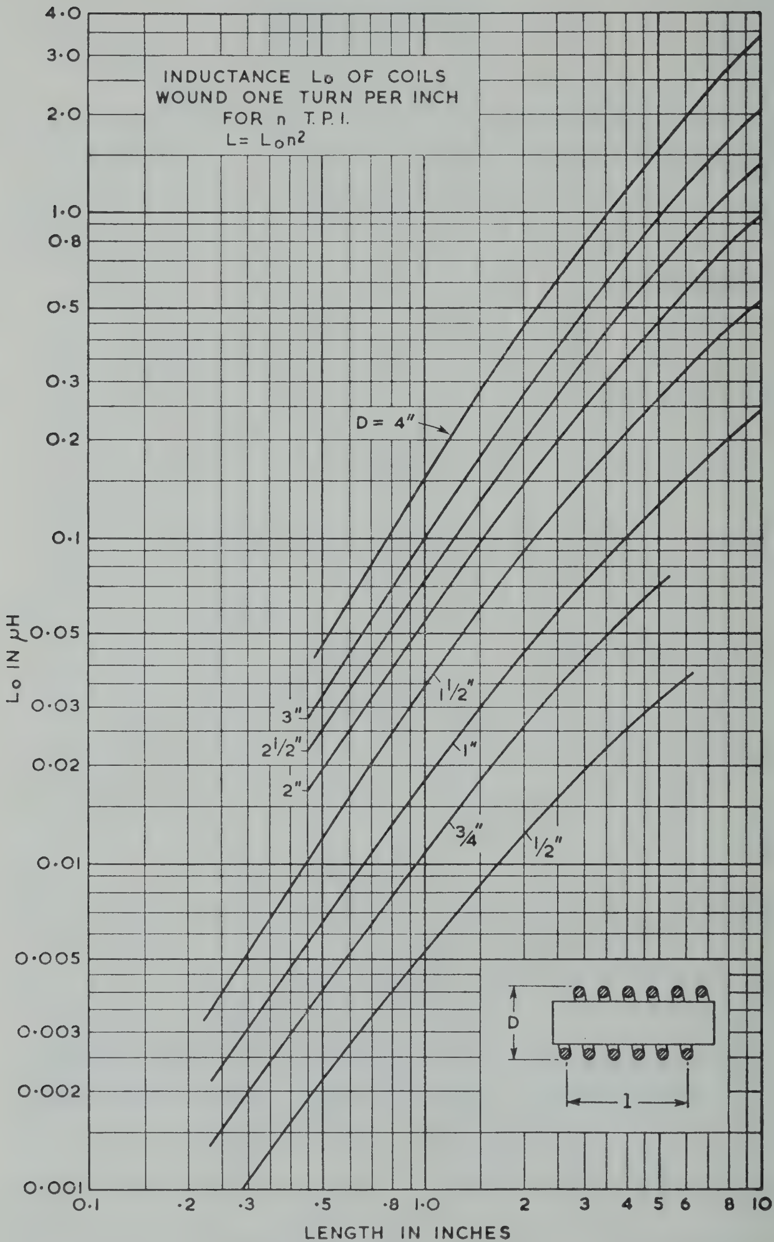


Fig. 21.

The chart, Fig. 16, gives the curves for $Q = 5, 10, 15, 20$ and 25. Having found Q_2 from the curves then $X_{c2} = \dfrac{R_2}{Q_2}$

$$X_{c1} = \frac{R_a}{Q - Q_2}$$

$$X_L = \frac{R_2 \cdot Q}{1 + Q_2^2}$$

It should be noted that the ratio $\dfrac{R_a}{R_2}$ which corresponds to $Q_2 = 0$, is a theoretical maximum ratio for the value of Q assumed. In fact X_{c2} is infinity at this ratio (that is, C_2 has disappeared) and the practical limit is a somewhat smaller ratio.

Worked example

An amplifier requiring an anode load of 500 ohms is required to match a 50 ohms aerial feeder.

$$\frac{R_a}{R_2} = \frac{500}{50} = 10$$

Let us select a loaded Q of 15—
from Fig. 16, $Q_2 = 3{\cdot}5$, hence $Q_1 = 15 - 3{\cdot}5 = 11{\cdot}5$

from equation 12, $$\frac{X_L}{R_2} = \frac{15}{1 + 3{\cdot}5^2} = 1{\cdot}132$$

Hence $$X_{c2} = \frac{50}{3{\cdot}5} = 14{\cdot}3 \text{ ohms}$$

$$X_{c1} = \frac{500}{11{\cdot}5} = 43{\cdot}5 \text{ ohms}$$

$$X_L = 1{\cdot}132 \times 50 = 56{\cdot}6 \text{ ohms}$$

so that for any given frequency, the values of C_1, C_2 and L, can now be calculated.

Design for the L-Pi network

The L-Pi network can readily be designed by this method if it is regarded as two Pi networks, back to back, in which the input capacitance is provided wholly by the output capacitance of the transistor.

The circuit then becomes Fig. 22

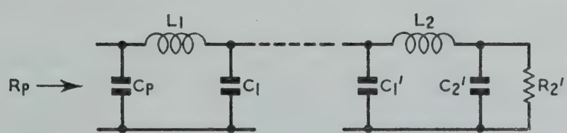


Fig. 22.

The following is an example where it is needed to match a 2N3632 transistor of output capacitance = 22pF and requiring a load of 29 ohms, into a final load of 72 ohms. Q values of 10 for the first network and 15 for the second network were assumed and the design for use at 144 MHz where the reactance of 22pF is 50 ohms.

Now $\frac{R_p}{X_p} = \frac{29}{50} = 0{\cdot}58$, let us call this Q_2

as the transformation in the first section is from low to high impedance. From Fig 16, $\frac{R_a}{R_2}$ can be seen to be 66 for $Q_2 = 0{\cdot}58$ and $Q = 10$. Hence the effective load across the output of the first section is $66 \times 29 = 1920$ ohms. Since

$$Q_1 = 10 - 0{\cdot}58 = 9{\cdot}42$$

$$X_{c1} = \frac{1920}{9{\cdot}42} = 204 \text{ ohms}$$

also $$\frac{X_{L1}}{R_2} = \frac{10}{1 + 0{\cdot}58^2} = 7{\cdot}49$$

$$X_{L1} = 29 \times 7{\cdot}49 = 218 \text{ ohms}$$

The second network, must now match 1920 ohms to the 72 ohms (aerial feeder),

hence $$\frac{R_a{}^1}{R_2{}^1} = 26{\cdot}6 \text{ and for } Q = 15$$

Fig. 16 shows $$Q_2 = 2{\cdot}3$$

hence $$X_{c2}{}^1 = \frac{72}{2{\cdot}3} = 31{\cdot}3 \text{ ohms}$$

now $$Q_1 = 15 - 2{\cdot}3 = 12{\cdot}7$$

hence $$X_{c1}{}^1 = \frac{1920}{12{\cdot}7} = 151 \text{ ohms}$$

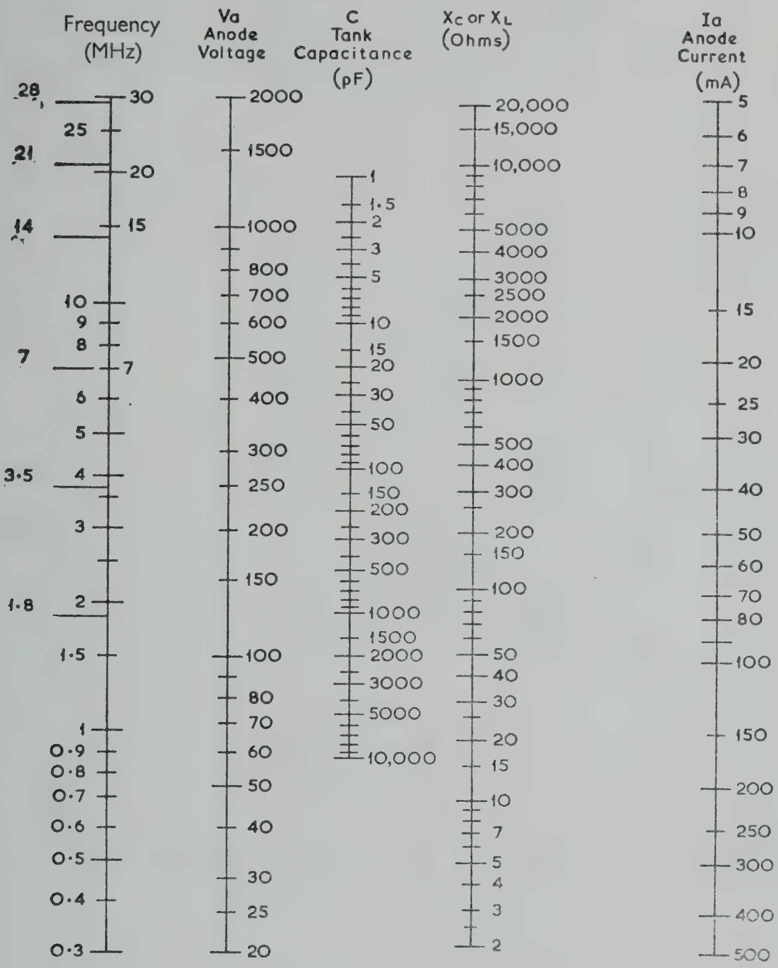
from equation 12, $$\frac{X_{L2}}{R_2{}^1} = \frac{15}{1 + 2{\cdot}3^2} = 2{\cdot}38$$

$$X_{L2} = 2{\cdot}38 \times 72 = 172 \text{ ohms}$$

GREEK ALPHABET

Capital letters	Small letters	Greek name	English equivalent	Capital letters	Small letters	Greek name	English equivalent
Α	α	*Alpha*	a	Ν	ν	*Nu*	n
Β	β	*Beta*	b	Ξ	ξ	*Xi*	x
Γ	γ	*Gamma*	g	Ο	ο	*Omicron*	ŏ
Δ	δ	*Delta*	d	Π	π	*Pi*	p
Ε	ε	*Epsilon*	e	Ρ	ρ	*Rho*	r
Ζ	ζ	*Zeta*	z	Σ	ς	*Sigma*	s
Η	η	*Eta*	é	Τ	τ	*Tau*	t
Θ	θ	*Theta*	th	Υ	υ	*Upsilon*	u
Ι	ι	*Iota*	i	Φ	φ	*Phi*	ph
Κ	κ	*Kappa*	k	Χ	χ	*Chi*	ch
Λ	λ	*Lambda*	l	Ψ	ψ	*Psi*	ps
Μ	μ	*Mu*	m	Ω	ω	*Omega*	ō

ANODE CIRCUIT CHART



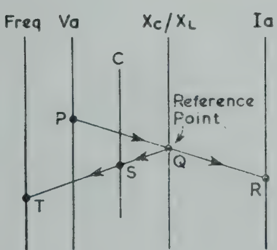
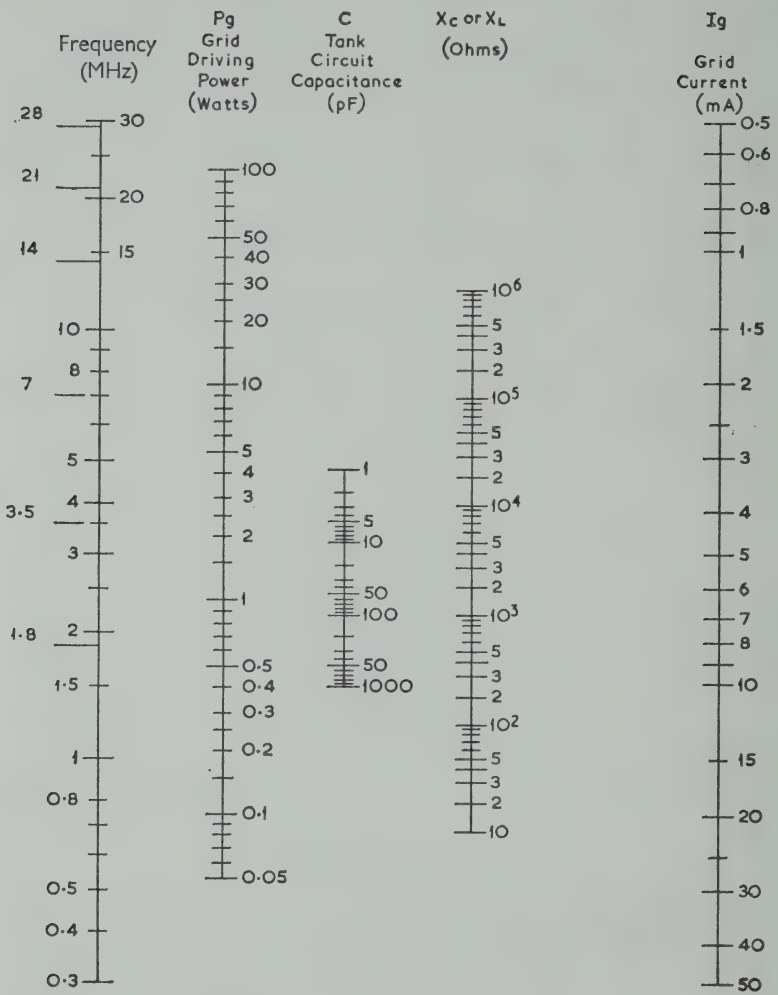


Fig. 23.

Abac for determining anode tank-circuit capacitance for a loaded Q of 12. For push-pull and parallel connections, the appropriate value of anode current is that for the two valves taken together. Use of the abac is illustrated at left. Join the selected values of *Va* and *Ia* by a line *PQR*. Note the point Q on the X_c/X_L scale. Join the point Q to the appropriate frequency *T* on the extreme left-hand scale. The required value of *C* is given at the point *S*. The corresponding value of *L* is given by the reactance value *XL* at the point Q divided by 6·28 × frequency (in MHz). Alternatively, *L* can be obtained from the reactance chart Fig. 26.

GRID CIRCUIT CHART



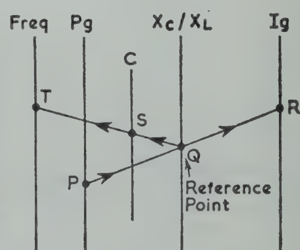


Fig. 24.

Abac for determining grid tank circuit capacitance for a Q value of 12. Use of the abac is illustrated at right. Join the selected values of *Pg* and *Ig* by a line *PQR*. Note the point Q on the X_c/X_L scale. Join the point Q to the appropriate frequency *T* on the extreme left-hand scale. The required value of C is given at the point *S*. The corresponding value of *L* is given by the reactance value X_L at the point Q divided by 6·28 × frequency (in MHz). Alternatively, *L* can be obtained from the reactance chart Fig. 26. For push-pull and parallel connections, the appropriate values of grid current and power are those for the two valves together.

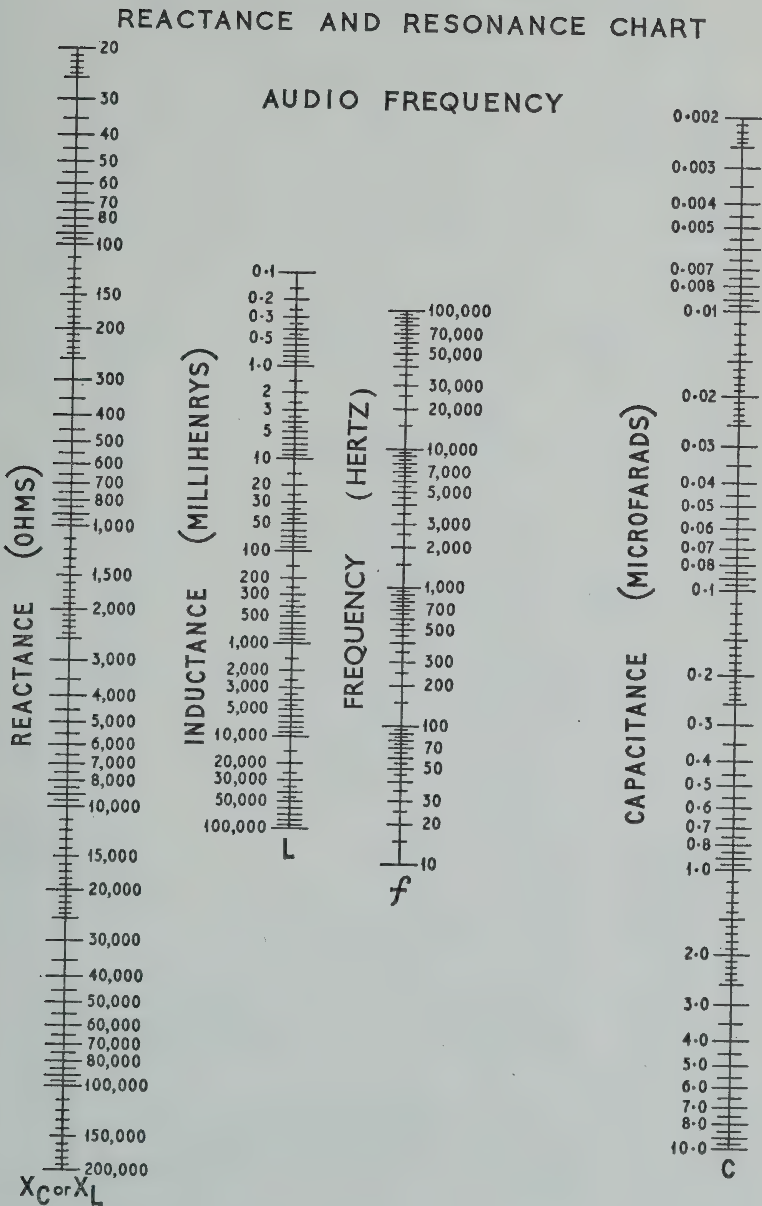
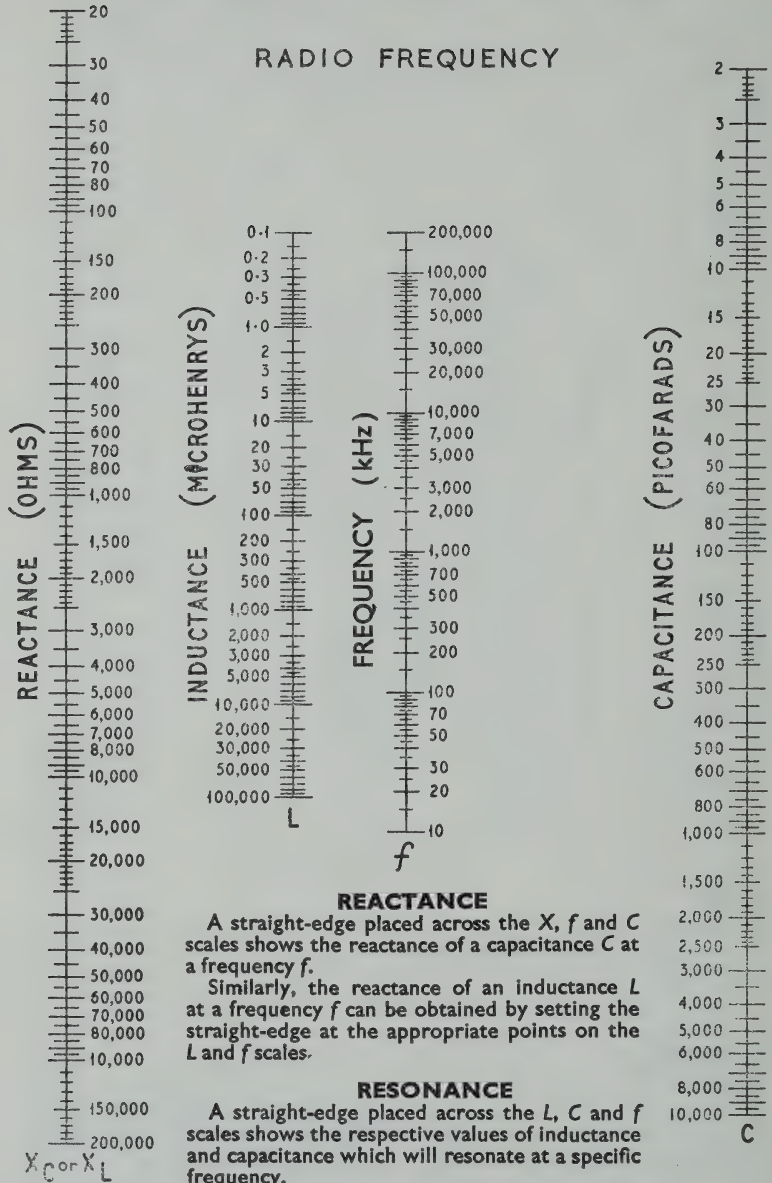

REACTANCE AND RESONANCE CHART
AUDIO FREQUENCY
REACTANCE (OHMS)
20
30
40
50
60
70
80
100
150
200
300
400
500
600
700
800
1,000
1,500
2,000
3,000
4,000
5,000
6,000
7,000
8,000
10,000
15,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
100,000
150,000
200,000
X_C or X_L
INDUCTANCE (MILLIHENRYS)
0·1
0·2
0·3
0·5
1·0
2
3
5
10
20
30
50
100
200
300
500
1,000
2,000
3,000
5,000
10,000
20,000
30,000
50,000
100,000
L
FREQUENCY (HERTZ)
100,000
70,000
50,000
30,000
20,000
10,000
7,000
5,000
3,000
2,000
1,000
700
500
300
200
100
70
50
30
20
10
f
CAPACITANCE (MICROFARADS)
0·002
0·003
0·004
0·005
0·007
0·008
0·01
0·02
0·03
0·04
0·05
0·06
0·07
0·08
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
1·0
2·0
3·0
4·0
5·0
6·0
7·0
8·0
10·0
C

Fig. 25.

REACTANCE AND RESONANCE CHART

RADIO FREQUENCY



REACTANCE

A straight-edge placed across the *X*, *f* and *C* scales shows the reactance of a capacitance *C* at a frequency *f*.

Similarly, the reactance of an inductance *L* at a frequency *f* can be obtained by setting the straight-edge at the appropriate points on the *L* and *f* scales.

RESONANCE

A straight-edge placed across the *L*, *C* and *f* scales shows the respective values of inductance and capacitance which will resonate at a specific frequency.

Fig. 26.

BIPOLAR AND FIELD EFFECT TRANSISTORS

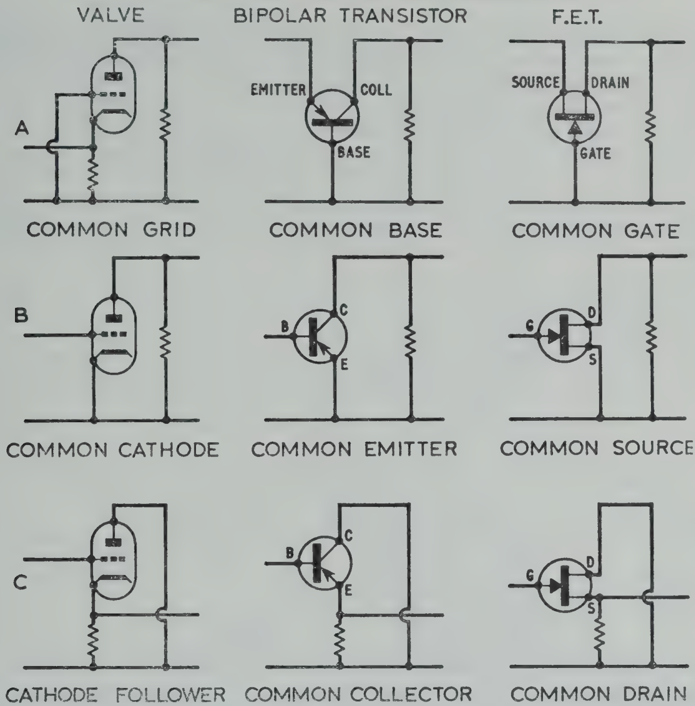


Fig. 27.

General Characteristics

	Circuit Configuration A	B	C
Current Gain	<1	High	High
Voltage Gain	High	High	<1
Input Impedance	Low	Medium	High
Output Impedance	High	Medium	Low
Power Gain	Medium	High	Low
Cut-off Frequency	High	Low	depends on load res.
Voltage Phase Shift (L.F.)	≈Zero	≈180°	≈Zero

The major differences between bipolar transistors and FET types may be summarized as follows:

(a) ***Input Impedance***

The input impedance of an FET is high because the input connection is into a reverse biased junction. A bipolar transistor has a low input impedance because the input is into a forward biased diode.

(b) ***Operation***

The FET is a voltage operated device whereas the bipolar transistor is current operated.

(c) ***Output Impedance***

The FET has a high output impedance and is similar to a bipolar transistor operating in the grounded base configuration.

WIDEBAND COUPLERS

Most wideband couplers consist of two tuned circuits, individually resonant at the same frequency and coupled together. The coupling is usually inductive, but the general characteristics are the same with any type. From Fig. 28, it can be seen that as the coupling is increased from zero, the single-peaked response rises to a maximum, flattens out, then divides into two peaks. Further increase in coupling results in greater separation and sharpness of the peaks. Note that the twin peaks are not caused by detuning, but by close coupling of two circuits tuned to the same frequency. The coupling coefficient is the ratio of the mutual inductance between windings to the inductance of one winding. This is true where the primary and secondary are identical; for simplicity, this is taken to be the case.

When the peak of the response is flat and on the point of splitting, the coupling is at its critical value, which is given by:

$$k_c = \frac{1}{Q}(Q_p = Q_s)$$

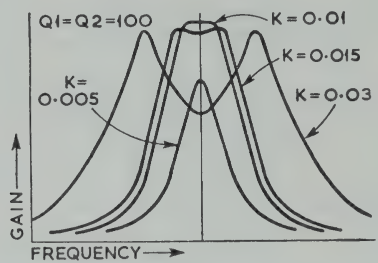


Fig. 28. Effect of varying the coupling between the coils in a wideband coupler (after Terman).

Hence, the higher the Q, the lower the coupling required. In a normal i.f. transformer, the coupling is set at the critical value; however, for use in wideband couplers, it is convenient to have it slightly higher. The design formulæ and practical values given below are based on a coupling/critical coupling ratio of 1·86, corresponding to a peak-to-trough ratio of 1·2 : 1, or a response flat within 2db over the band. Other values can be obtained from the references.

The most convenient way of introducing variable coupling between two tuned circuits is with a small trimmer between the " hot " ends of the coils (see Fig. 29). This is equivalent, except where phase relationships are concerned, to a mutual inductance of the value:

$$M = \frac{C_1}{C_1 + C} L$$

Hence the coupling coefficient is:

$$k = \frac{C_1}{C_1 + C}$$

The purpose of the damping resistors shown in Fig. 29 is to obtain correct circuit Q; they should not be omitted, unless triodes are used. The secondary damping resistors are also the grid resistors of the next stage, and should never be omitted. In class A amplifiers, they may be simply shunted across the secondary with no blocking capacitor. In wideband multipliers, R should be the same for all brands, so that the output stage grid resistor will be correct for each coupler. Primary and secondary coils should be as near identical as possible, and tuning done

with trimmers only. This does not apply to the 28 MHz coupler as strays necessitate the use of dissimilar *Qs*.

Given set values of damping resistance, passband, and centre frequency, all values may be calculated from the following formulæ:

$$k = 0{\cdot}84 \; \frac{Bandwidth\,(kHz)}{Centre\ frequency\,(kHz)}$$

$$Q = \frac{1{\cdot}86}{k}$$

$$L = \frac{R}{2\pi f Q}$$

$$C = \frac{1}{L}\left(\frac{1}{2\pi f}\right)^2$$

where C is in μF, L is in μH and f is the centre frequency in MHz. R is in ohms.

Note that C includes all strays; if the calculated value of C is less than the estimated strays on any band, a lower value of R should be used. The bandswitch can increase the strays to 20 pF (0·00002 μF) or more.

Coupling capacitance, $C1$, is given by:

$$C1 = \frac{k}{1-k}\,C$$

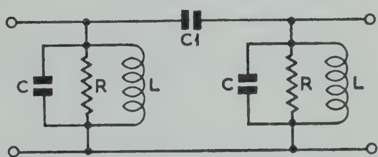


Fig. 29. Basic coupler circuit.

As the percentage bandwidth on 21 MHz is so low, this band could be covered adequately by a single low-Q tuned circuit such as a self-resonant coil. However, values for this band are given in Table 1, which is based on a value for R of 15K ohms on all bands. The coverage of some of the couplers is greater than the band limits, as they are needed to multiply up to 30 MHz. The 28 MHz coupler was specially designed with different primary and secondary *Qs*, as the strays were greater on the output side than the identical-Q coupler tuning capacitance. This coupler allows 30 pF total capacitance, which should be ample for most layouts. The anode side strays are covered adequately by 10 pF, as there is no switch and only 2 pF anode-to-cathode capacitance and wiring strays. The coil data is for ⅜ in. diameter formers, and a total winding length of ¾ in.

TABLE I
AMATEUR BAND COUPLER DATA

Lowest Frequency	Centre Frequency	Highest Frequency	Coupling	Parallel Capacity	L	Winding Details
3·5 MHz	3·65 MHz	3·8 MHz	6 pF	78 pF	24μH	60 turns 32 s.w.g. close-wound
7	7·25	7·5	3	47	10	40 turns 28 s.w.g. close-wound
14	14·5	15	1·5	24	5	27 turns 24 s.w.g. close-wound
21	21·225	21·45	1	52	1	12 turns 20 s.w.g. spaced to ¾ in.
28	29	30	0·6	pri. 10	3	21 turns 24 s.w.g. spaced to ¾ in.
				sec. 30	1	12 turns 20 s.w.g.

The formers used are all ⅜ in. dia. and the winding lengths of the coils ¾ in. The use of slugged formers is not recommended. On all bands except 28 MHz, primary and secondary are identical. Each coupler should be adjusted to cover the frequency range shown. Damping resistors are 15 K ohms on all bands.

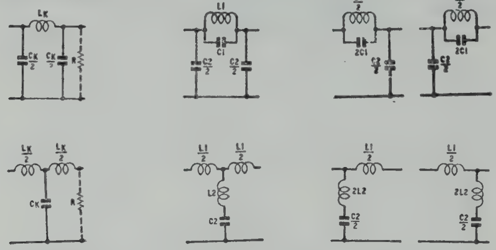
FILTER NETWORKS

Constant K | m-derived | m-derived end sections for use with constant k or m-derived centre sections

LOW PASS

T

π



$$C1 = \frac{1 - m^2 C_k}{4m}$$

$$C2 = mC_k$$

$$C_k = \frac{1}{\pi f_c R}$$

$$L1 = mL_k$$

$$L2 = \frac{1 - m^2 L_k}{4m}$$

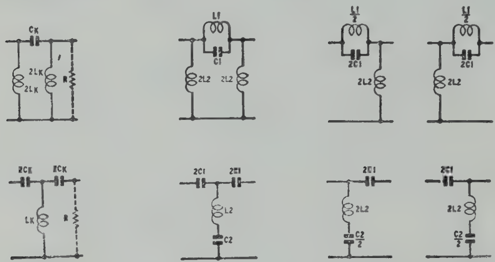
$$L_k = \frac{R}{\pi f_c}$$

$$m = \sqrt{1 - \left(\frac{f_c}{f_m}\right)^2}$$

HIGH PASS

T

π



$$C1 = \frac{C_k}{m}$$

$$C2 = \frac{4m}{1 - m^2} C_k$$

$$C_k = \frac{1}{4\pi f_c R}$$

$$L1 = \frac{4m}{1 - m^2} L_k$$

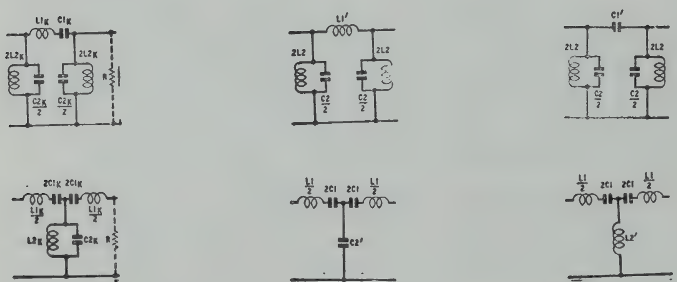
$$L2 = \frac{L_k}{m}$$

$$L_k = \frac{R}{4\pi f_c}$$

$$m = \sqrt{1 - \left(\frac{f_m}{f_c}\right)^2}$$

BAND PASS

Constant K | Three element



$$L1_k = \frac{R}{\pi(f_2 - f_1)}$$

$$L2_k = \frac{f_2 - f_1 R}{4f_2 f_1}$$

$$C1_k = \frac{f_2 - f_1}{4\pi f_2 f_1 R}$$

$$C2_k = \frac{1}{\pi(f_2 - f_1)R}$$

Constant K

$$L1 = L1_k$$

$$L1' = \frac{R}{\pi(f_1 - f_2)}$$

$$C1 = \frac{f_2 - f_1}{4\pi f_1^2 R}$$

$$L2 = \frac{f_2 - f_1 R}{4\pi f_1^2}$$

$$C2 = C2_k$$

$$C2' = \frac{1}{\pi(f_1 + f_2)R}$$

Three element

$$L1 = \frac{f_1 R}{\pi f_2(f_2 - f_1)}$$

$$C1 = C1_k$$

$$C1' = \frac{f_1 + f_2}{4\pi f_1 f_2 R}$$

$$L2 = L2_k$$

$$L2' = \frac{(f_1 + f_2)R}{4\pi f_1 f_2}$$

$$C2 = \frac{f_1}{\pi f_2(f_2 - f_1)R}$$

Fig. 30. C in farads. L in henries. R in ohms. f_c (cut-off frequency), f_m (frequency of maximum attenuation), f_1 (lower cut-off frequency) and f_2 (upper cut-off frequency) in cycles per second.

TYPICAL PRACTICAL TVI FILTERS

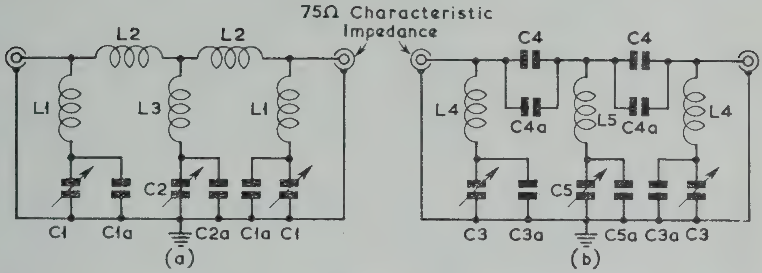


Fig. 31. (a) Low pass filter. (b) High pass filter. The fixed capacitors, marked "a" indicate that the capacitor is in fact made up of fixed and variable capacitors as shown below . The low pass filter is for transmitter output circuits and the high pass filter is for use in television receiver inputs. Maximum attenuation is between 32 and 38 MHz.

Coil Table for Fig. 31

In both low and high pass filters all inductors are wound with 18 s.w.g. enamelled copper wire on a $\frac{3}{8}$ in. mandrel (former).

Low Pass Filters

L1 (two required). Total length of wire including leads $13\frac{1}{2}$ in. 9 turns close wound, opened to $\frac{11}{16}$ in. winding length (Inductance 0·4 μH).

L2 (two required). Total length of wire including leads $9\frac{3}{4}$ in. 6 turns close wound, opened to $\frac{9}{16}$ in. winding length (Inductance 0·225 μH).

L3 (one required). Total length of wire including leads $8\frac{1}{2}$ in. 5 turns close wound, opened to $\frac{7}{16}$ in. winding length (Inductance 0·2 μH).

High Pass Filter

L4 (two required). Total length of wire including leads $14\frac{3}{4}$ in. 10 turns close wound, opened to $\frac{11}{16}$ in. winding length (Inductance 0·49 μH).

L5 (one required). Total length of wire including leads $9\frac{3}{4}$ in. 6 turns close wound, opened to $\frac{1}{2}$ in. winding length (Inductance 0·24 μH).

CAPACITOR TABLE

Low Pass Filter

C1 (two required). Total capacitance 52 pF maximum made up of a 5–35 pF ceramic variable in parallel with 17 pF fixed.

C2 (one required). Total capacitance 85 pF maximum made up of 5–35 pF ceramic variable in parallel with a 50 pF fixed.

Although ceramic variable capacitors are suggested above on the grounds of economy, air spaced variables are to be preferred for use in filters for transmitters in the high-power class. Other combinations of variable and fixed capacity may be used provided the total meets the specification. At least 20 pF variable capacity should be allowed.

High Pass Filter

C3 (two required). Total capacitance 65 pF maximum made up of a 5–35 pF ceramic variable in parallel with 30 pF fixed.

C4 (two required). Total capacitance 83 pF comprising close tolerance capacitors of 33 pF and 50 pF in parallel.

C5 (one required). Total capacitance 103 pF maximum made up of a 5–35 pF ceramic variable in parallel with 68 pF fixed.

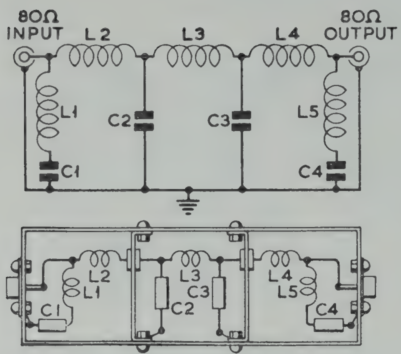


Fig. 32. Circuit and layout of a four-section low pass filter suitable for use with any transmitter on all bands 1·8—30 MHz. It is designed for insertion in an 80-ohm coaxial feeder.

C1, C4 — 36 pF mica, 750 V d.c. working (5% tolerance).
C2, C3 — 120 pF mica, 750 V d.c. working (5% tolerance).
L1, L5 — 0·36 μH: 7 turns, winding length 1 in.
L2, L4 — 0·59 μH: 10 turns, winding length 1 in.
L3 — 0·73 μH: 12 turns, winding length $1\frac{3}{16}$ in.

All coils are of No. 16 s.w.g. copper wire, $\frac{1}{2}$ in. internal diameter self-supporting, with a connecting lead 1 in. long at each end.

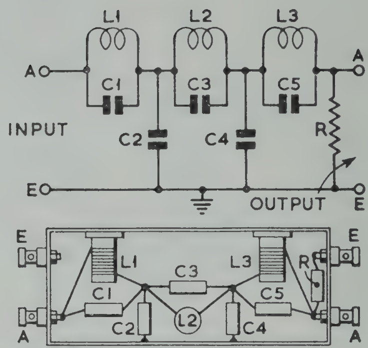


Fig. 33. Circuit and layout of a low pass filter suitable for use with a medium-wave broadcast receiver.

	Calculated values	*Suggested nominal values*
C1, C5	**327 pF**	**330 pF**
C2, C4	**357 pF**	**360 pF**
C3	**26.2 pF**	**27 pF**

L1, L3 — 21·45 μH: 50 turns No. 32 s.w.g. enamelled copper wire on Aladdin former, type F804, with dust-iron core.

L2 — 71·7 μH: 90 turns No. 38 s.w.g. enamelled copper wire on Aladdin former, type F804, with dust-iron core.

R — 400 ohm, $\frac{1}{4}$ W (10% tolerance).

HALF-WAVE FILTERS

Filters of this type are extremely effective when used on the band for which they are designed. The minor disadvantage that a filter is required for each band is largely offset by the simplicity of construction from readily available components. In the table below, all capacitors are disc ceramic* type and should be rated at a minimum of 1000 volts working for use with a.m. transmitters running inputs of up to 150 watts. The inductances are all wound with 12 s.w.g. tinned copper wire, eight turns per inch. Allowance has been made for leads of $\frac{1}{2}$ in. The values are for filters suitable for cables having impedances between 50 and 75 ohms.

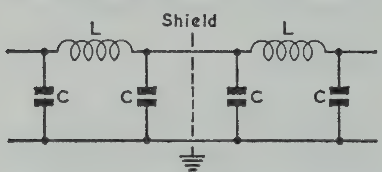


Fig. 34. Circuit arrangement of a half-wave filter.

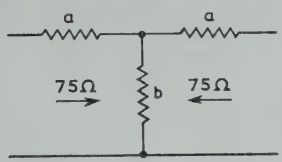
Capacitors and Inductors for Half-wave Filters

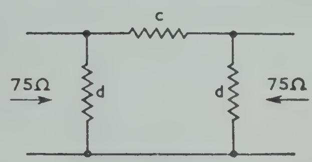
3·5 MHz	C, 800 pF.	L, 2·3 μH	($11\frac{1}{2}$ turns, 1 in. long, 1 in. inside diameter).
7 MHz	C, 500 pF	L, 1·0 μH	($10\frac{1}{2}$ turns, $\frac{3}{4}$ in. inside diameter).
14 MHz	C, 220 pF	L, 0·55 μH	($6\frac{1}{2}$ turns, $\frac{3}{4}$ in. inside diameter).
21 MHz	C, 150 pF	L, 0·37 μH	($7\frac{1}{2}$ turns, $\frac{1}{2}$ in. inside diameter).
28 MHz	C, 110 pF	L, 0·28 μH	(6 turns, $\frac{1}{2}$ in. inside diameter).

* High grade mica also suitable.

75 OHM ATTENUATOR, FOR INSERTION IN AERIAL INPUT OF A RECEIVER

	T PAD		π PAD	

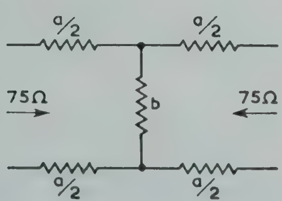




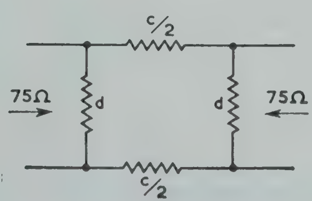
Loss in db	a ohms	b ohms	c ohms	d ohms
1	4·31	647·3	8·65	1,304·5
2	8·60	322·9	17·43	654·1
3	12·81	212·9	26·39	439·0
4	16·97	157·3	35·78	331·4
5	21·00	123·4	45·63	267·8
6	24·93	100·4	56·01	225·8
7	28·70	83·75	67·16	196·1
8	32·30	70·94	79·26	174·3
9	35·70	60·90	92·36	157·5
10	38·96	52·74	106·6	144·4
11	42·02	45·90	122·5	133·9
12	44·90	40·21	139·9	125·4
13	47·56	35·33	159·1	118·3
14	50·05	31·16	180·5	112·4
15	52·35	25·01	204·1	107·4
20	61·36	15·15	371·3	91·67
25	67·00	8·45	665·5	83·93
30	70·40	4·75	1,186	79·87
35	72·38	2·67	2,108	77·70
40	73·64	1·50	3,750	76·51
45	74·16	0·844	6,669	75·85
50	74·53	0·474	11,858	75·48

For attenuators of characteristic impedance R, the values of a, b, c and d given may be multiplied by the factor R/75. Equivalent configurations for balanced attenuators giving the same loss are given below.

Balanced T Pad



Balanced π Pad



TRANSMISSION LINE RESONATORS

When designing a resonator to be used as a tank circuit it is necessary to know first how long to make the lines. The resonant frequency of a capacitatively loaded shorted line, open-wire or coaxial, is given by the following expression:

$$\frac{1}{2\pi fC} = Z_0 \tan \frac{2\pi l}{\lambda}$$

where f *is the frequency*
C *is the loading capacitance*
λ *is the wavelength*
l *is the line length*
Z_0 *is the characteristic impedance of the line.*

The characteristic impedance is given by

$$Z_0 = 138 \log_{10} \frac{d_0}{d_1}$$

for a coaxial line with inside diameter of the outer d_0 and outside diameter of the inner conductor d_1

or
$$Z_0 = 276 \log_{10} \frac{2D}{d}$$

for an open-wire line with conductor diameter d and centre-to-centre spacing D.

The results obtained from these expressions have been put into the form of the simple set of curves shown in Fig. 31 on page 45.

In the graphs, fl has been plotted against fC for different values of Z_0, with f in MHz, C in pF and l in centimetres.

In the case of coaxial lines (the right-hand set of curves) r is the ratio of conductor diameters or radii and for open-wire lines (the left-hand set of curves) r is the ratio of centre-to-centre spacing to conductor diameter.

The following examples should make the use of the graphs quite clear:

Example 1

How long must a shorted parallel-wire line of conductor diameter 0·3 in. and centre-to-centre spacing 1·5 in. be made to resonate at 435 MHz, with an end-loading capacitance of 2 pF (the approximate output capacitance, in practice, of a QQV03-20 push-pull arrangement)

First, work out $f \times C$, in MHz and pF.

$$\begin{aligned} fC &= 435 \times 2 \\ &= 870 \\ &= 8{\cdot}7 \times 10^2. \end{aligned}$$

The ratio, r, of line spacing to diameter is:

$$r = \frac{1{\cdot}5}{0{\cdot}3} = 5{\cdot}0.$$

Then, from the curves marked "parallel-wire lines," $r = 5{\cdot}0$ project upwards from $8{\cdot}7 \times 10^2$ on the horizontal "$f \times C$" scale to the graph and project across from the point on the graph so found to the vertical "$f \times l$" scale, obtaining:

$$fl = 2800$$

$$\textit{therefore, } l = \frac{2800}{435} = 6{\cdot}45 \text{ cm. approximately.}$$

The anode pins would obviously absorb quite a good deal of this line length but, if the lines were made 6 cm. long, with an adjustable shorting-bar they would be certain to be long enough.

Example 2

A transmission line consisting of a pair of 10 s.w.g. copper wires spaced 1 in.

apart and 10 cm. long is to be used as part of the anode tank circuit of a TT15 or QQV06-40 p.a. at 145 MHz. How much extra capacitance must be added at the valve end of the line to accomplish this?

For a pair of wires approximately $\frac{1}{8}$ in. in diameter spaced 1 in. r is about 8. Also $f \times l$ is equal to 145×10, i.e. 1450. Estimating the position of the " $r = 8$ " curve for a parallel-wire line between " $r = 10$ " and " $r = 7$," $f \times C$ is found to be about $1{\cdot}55 \times 10^2$, i.e. 1550. Hence the total capacitance C required is given by

$$145 \times C = 1550$$
$$C = 1550 \div 145$$
$$= 10{\cdot}7 \text{ pF.}$$

Now the output capacitance of a TT15 or QQV06-40 push-pull stage is around 4 pF in practice, so about 7 pF is required in addition. A 25 + 25 pF split stator capacitor should therefore be quite satisfactory giving 12 to 15 pF extra at maximum capacitance.

Example 3

A coaxial line with outer and inner radii of 5·0 and 2·0 cm., respectively, is to be used as the resonant tank circuit (short-circuited at one end of course) for a 4X150A power amplifier on the 70 cm. amateur band. What length of line is required?

In this case: $f \times C = 435 \times 4{\cdot}6 = 2001.$

Using the " $r = 2{\cdot}5$ " curve for coaxial lines,

$$f \times l = 4620$$

Hence $l = 4620 \div 435 = 10{\cdot}6$ cm. approximately.

This length includes the length of the anode and cooler but, as in Example 1, a line 10 cm. long would be long enough, as the output capacitance used in the calculations is that quoted by the valve manufacturers, the effective capacitance being somewhat greater in practical circuits. A shorting bridge is the best method of tuning the line to resonance.

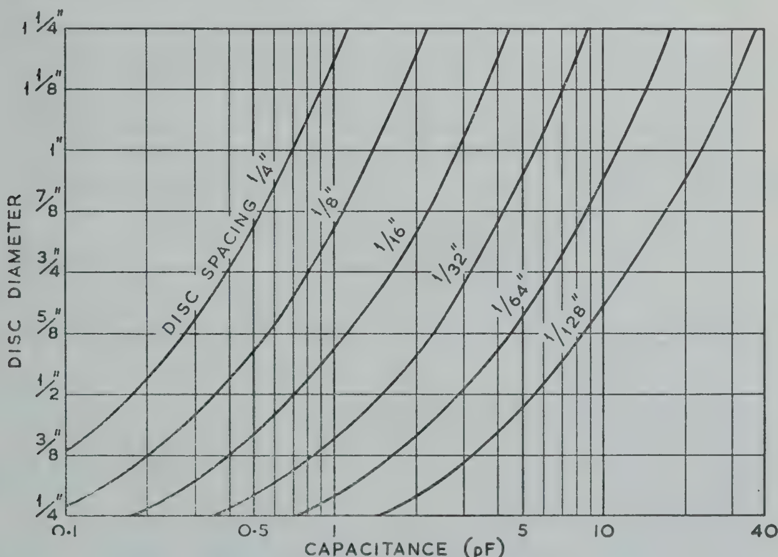


Fig. 35. Parallel lines or concentric tuned circuits are conveniently tuned by means of a variable air capacitor comprising two parallel discs. This chart shows the capacitance between two parallel discs of various diameters.

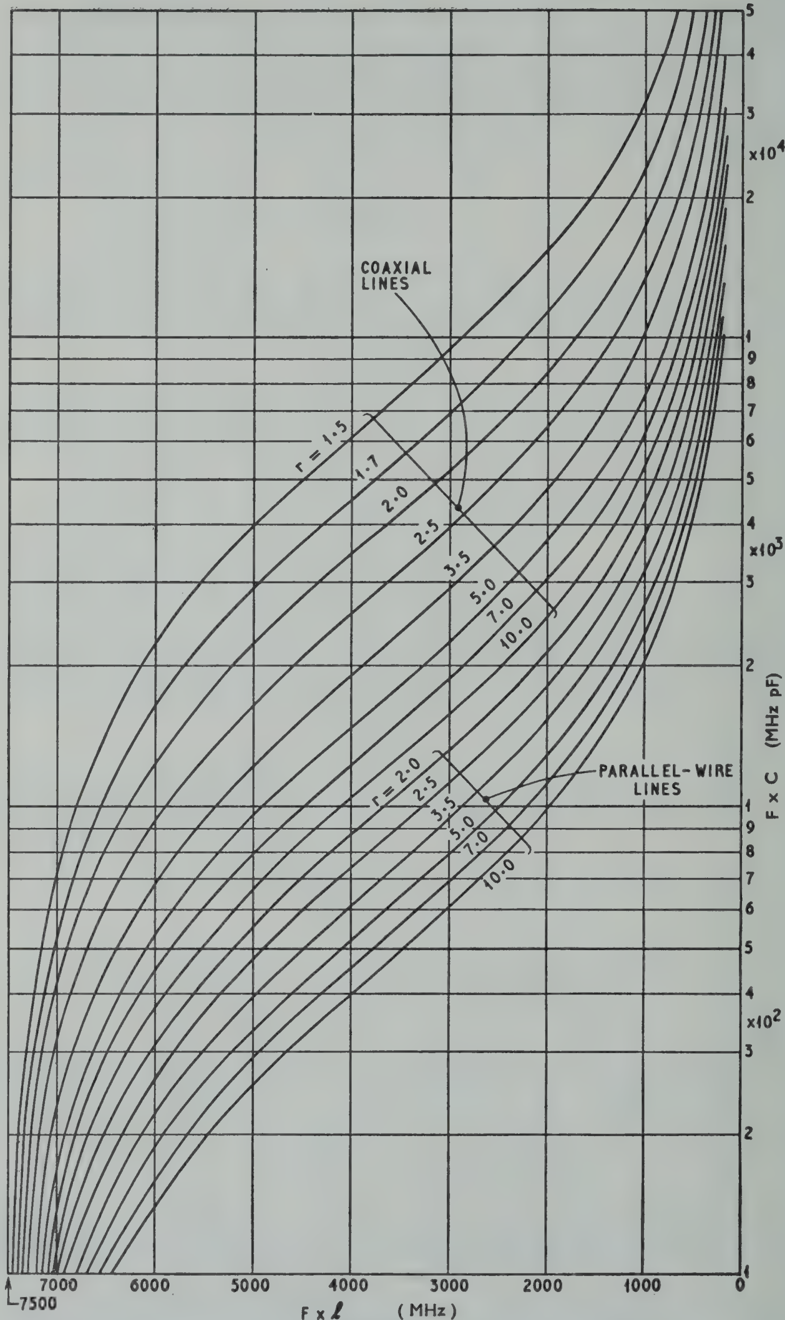


Fig. 36. Resonance curves for capacitively loaded transmission line resonators.

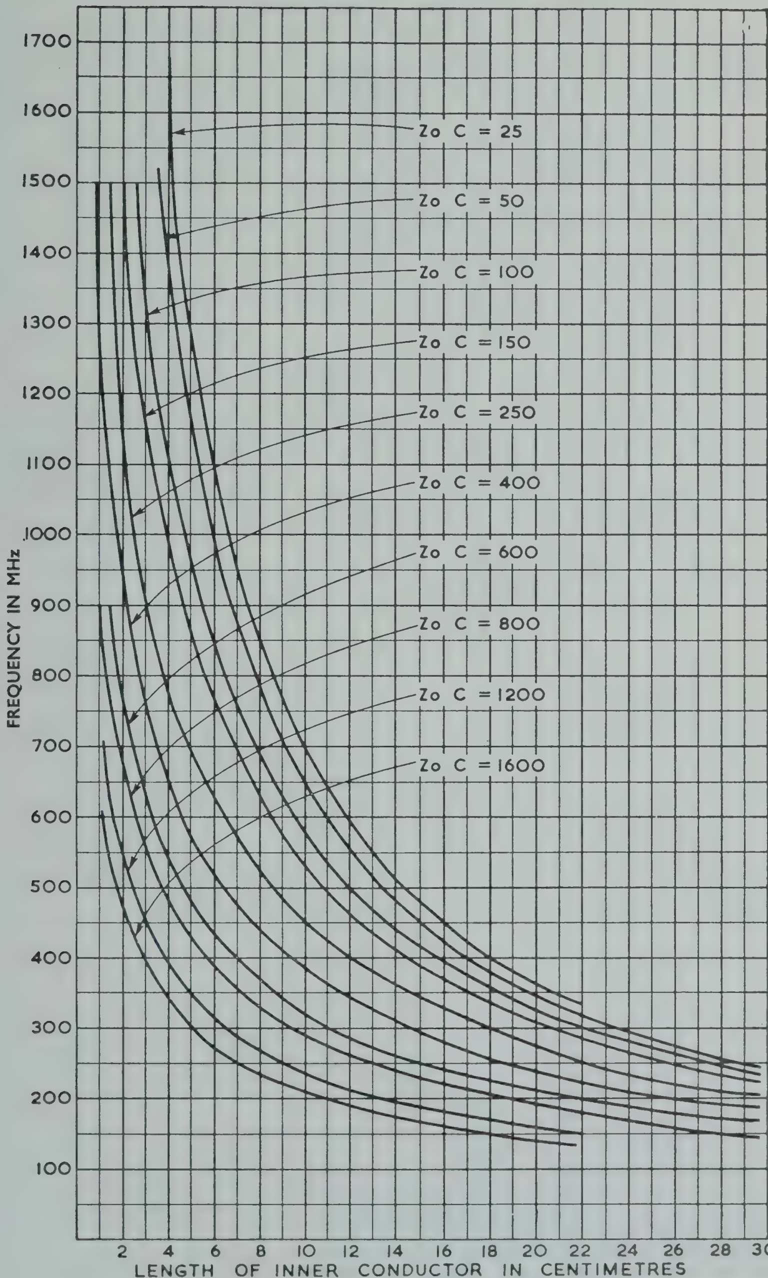


Fig. 37.
Chart plotting frequency against length of inner line for various values of the characteristic impedance multiplied by the total capacitance. C is in pF and Z_0 in ohms.

BALANCE-TO-UNBALANCE TRANSFORMERS

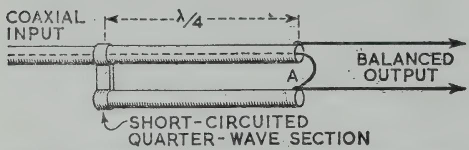


Fig. 38. Quarter-wave open balun or Pawsey stub.

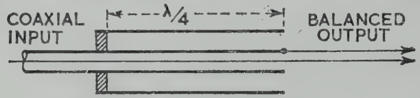


Fig. 39. Coaxial-sleeve balun.

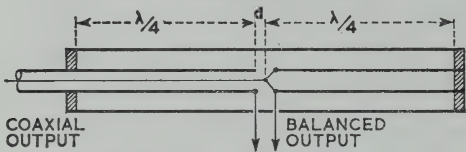


Fig. 40. Totally enclosed coaxial balun. The right-hand section acts as a "metal insulator."

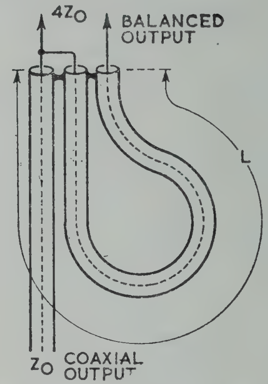


Fig. 41. Coaxial balun giving a 4 : 1 impedance step-up. The length *L* should be λ/2, allowing for the velocity factor of the cable. The outer braiding may be joined at the points indicated.

IMPEDANCE MATCHING

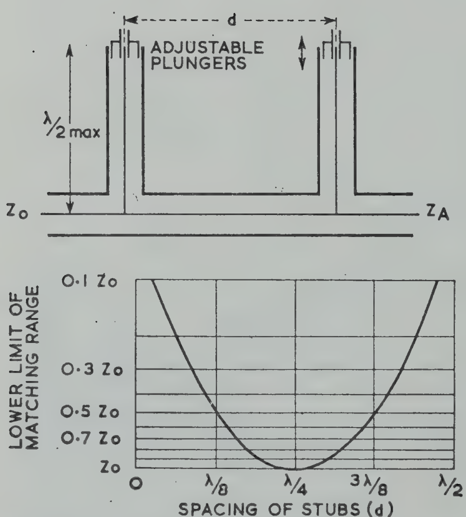


Fig. 42. Two-stub coaxial tuner. The graph shows the lower limit of the matching range: the upper limit is determined by the Q of the stubs (i.e. it is dependent on the losses in the stubs). Z_0 is the characteristic impedance of the feeder.

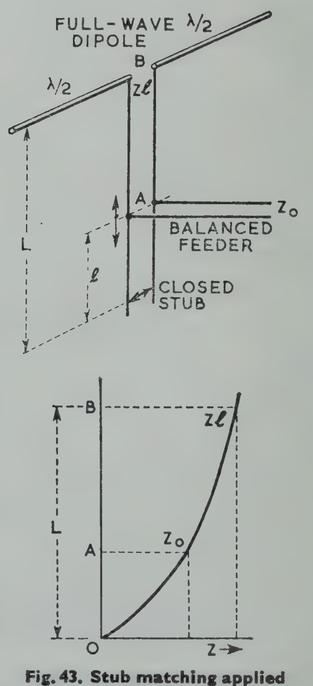


Fig. 43. Stub matching applied to a full-wave dipole.

STUB MATCHING

IMPEDANCE MATCHING WITH OPEN STUB

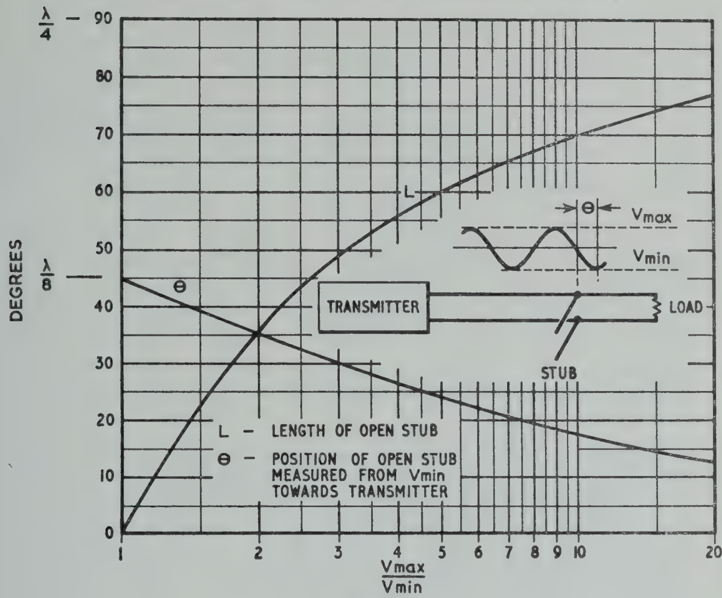


Fig. 44.

IMPEDANCE MATCHING WITH SHORTED STUB

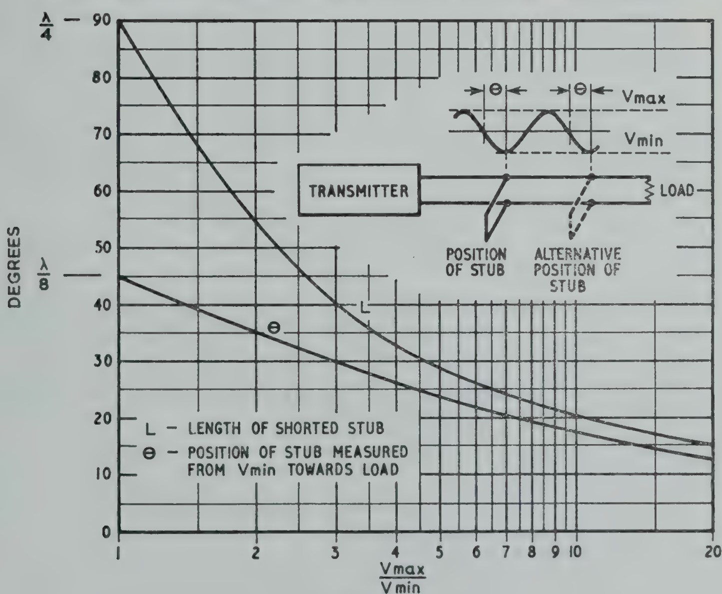


Fig. 45.

STANDING WAVE RATIO CHART

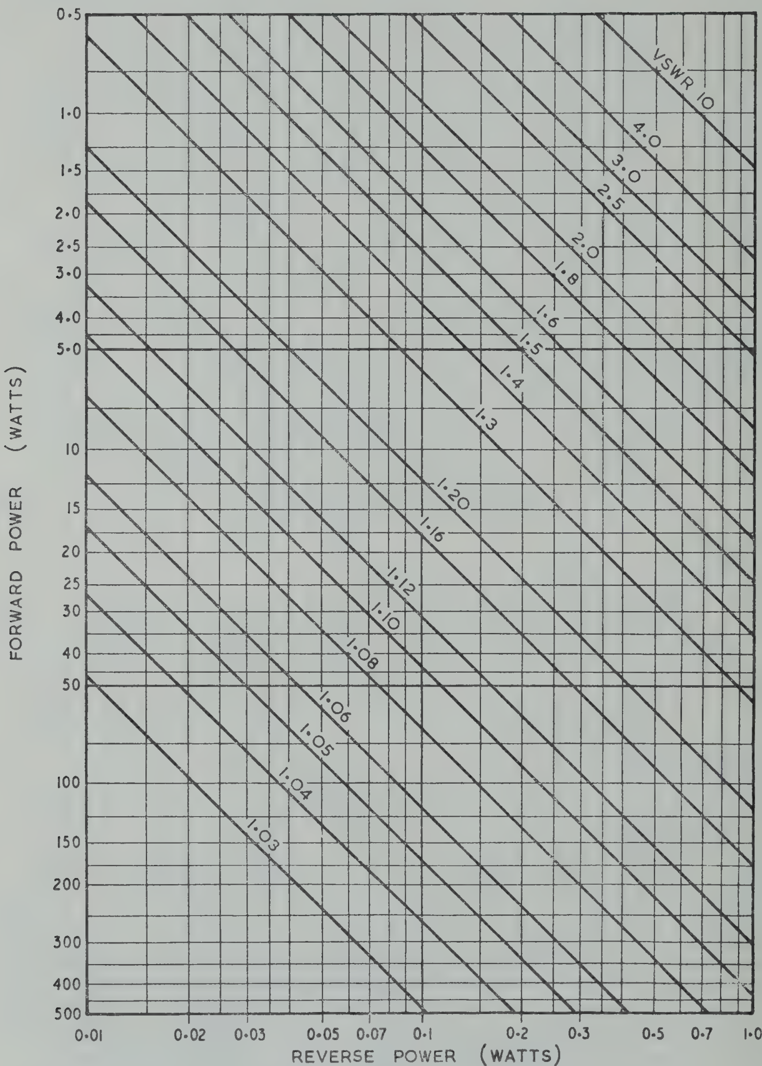
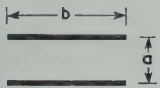


Fig. 46.

TRANSMISSION LINES

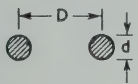
1 PARALLEL STRIPS (SLAB LINES)



$$Z_o \doteq 377\,\frac{a}{b}$$ if $a \ll b$

edge effects neglected

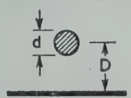
2 PARALLEL WIRE (TWIN LINE)



$$Z_o = 276 \log_{10}\left(\frac{D}{d} + \sqrt{\left(\frac{D}{d}\right)^2 - 1}\right)$$

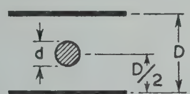
$$Z_o \doteq 276 \log_{10} \frac{2D}{d}$$ if $d \ll D$

3 WIRE PARALLEL TO INFINITE PLATE



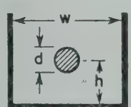
$$Z_o \doteq 138 \log_{10} \frac{D}{d}$$ if $d \ll D$

4 WIRE PARALLEL TO TWO INFINITE PLATES



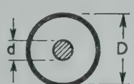
$$Z_o \doteq 138 \log_{10} \frac{4D}{\pi d}$$ if $d \ll D$

5 WIRE IN RECTANGULAR TROUGH



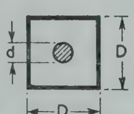
$$Z_o \doteq 138 \log_{10}\left(\frac{4w \tanh \frac{\pi h}{w}}{\pi d}\right)$$ if $d \ll h$, and w

6 CIRCULAR COAXIAL



$$Z_o = 138 \log_{10} \frac{D}{d}$$

7 SQUARE COAXIAL



$$Z_o \doteq 138 \log_{10} \frac{1{\cdot}178D}{d}$$

NOTE: In the above, the medium is taken as AIR.
For other medium, the resulting value of Z_o should be multiplied by $\frac{1}{\sqrt{K}}$

where K is the dielectric constant

Fig. 47.

FEEDER LINE IMPEDANCES

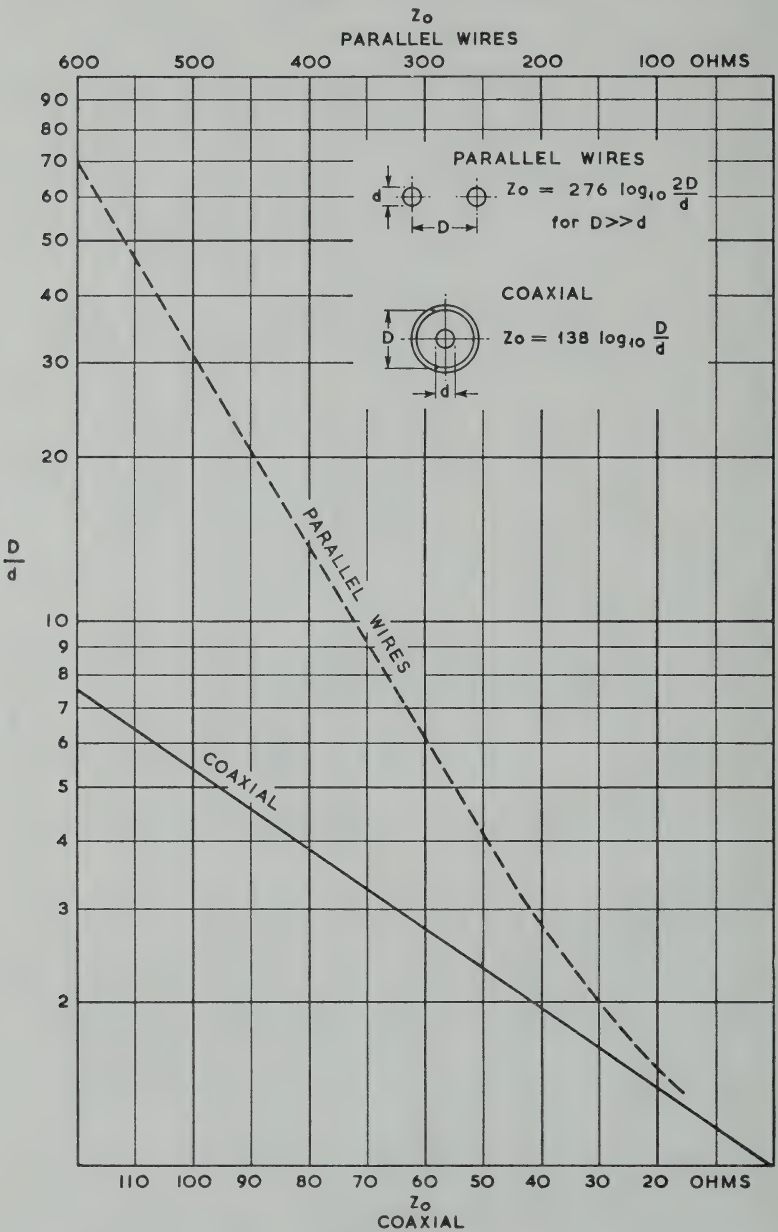


Fig. 48.

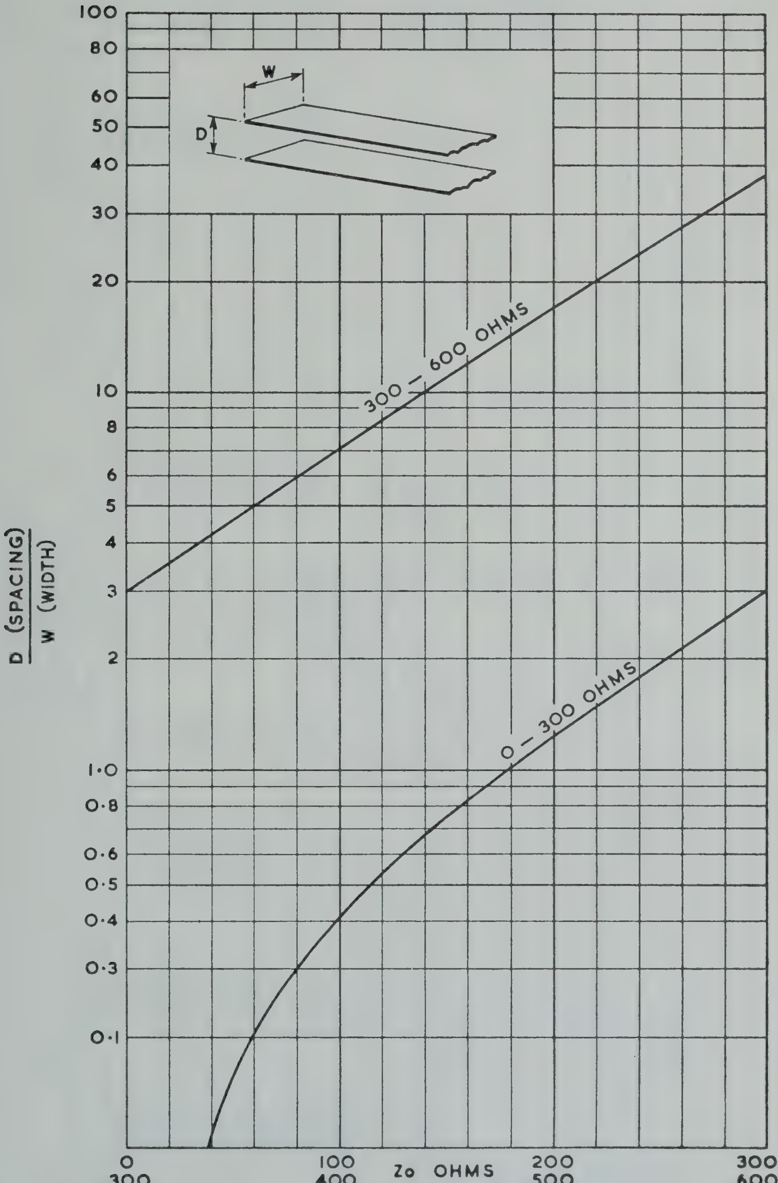


Fig. 49.
Characteristic impedance of balanced strip transmission line

CHARACTERISTICS OF TYPICAL BRITISH RADIO FREQUENCY FEEDER CABLES

Type of Cable	Nominal Impedance Z_0(ohms)	Centre Conductor	Dimensions (in.)		Velocity Factor	Approximate Attenuation (db per 100 ft.)				Remarks
			over outer sheath	over twin cores		70 MHz	145 MHz	430 MHz	1250 MHz	
Standard TV feeder ...	75	7/·0076	0·202	—	0·67	3·5	5·1	9·2	17	—
Low-loss TV feeder ... (semi-air-spaced) ...	75	0·048	0·290	—	0·86	2·0	3·0	5·4	10	Semi-air-spaced or cellular.
Flat twin...	150	7/·012	—	0·18 × 0·09	approx. 0·71	2·1	3·1	5·7*	11*	*Theoretical figures, likely to be considerably worsened by radiation
Flat twin...	300	7/·012	—	0·405 × 0·09	0·85	1·2	1·8	3·4*	6·6*	
Tubular twin	300	7/·012	—	0·446	0·85	1·2	1·8	3·4*	6·6*	

This table is compiled from information kindly supplied by *Aerialite Ltd.*, and *B.I.C.C. Ltd.* and includes data extracted from *Defence Specification*, DEF-14-A (H.M.S.O.)

R.F. CABLES—BRITISH UR SERIES

UR No.	Nominal Impedance Z_0 (ohms)	Overall diameter —inches	Inner conductor —inches	Capacity pF/ft.	Maximum Operating voltage R.M.S.	Approx. Attenuation db per 100 ft.				Approx. RG equivalent
						10 MHz	100 MHz	300 MHz	1000 MHz	
43	52	0·195	0·032	29	2750	1·3	4·3	8·7	18·1	58/U
57	75	0·405	0·044	20·6	5000	0·6	1·9	3·5	7·1	11A/U
63*	75	0·855	0·175	14	4400	0·15	0·5	0·9	1·7	
67	50	0·405	7/0·029	30	4800	0·6	2·0	3·7	7·5	213/U
74	51	0·870	0·188	30·7	15000	0·3	1·0	1·9	4·2	218/U
76	51	0·195	19/0·0066	29	1800	1·6	5·3	9·6	22·0	58C/U
77	75	0·870	0·104	20·5	12500	0·3	1·0	1·9	4·2	164/U
79*	50	0·855	0·265	21	6000	0·16	0·5	0·9	1·8	
83*	50	0·555	0·168	21	2600	0·25	0·8	1·5	2·8	
85*	75	0·555	0·109	14	2600	0·2	0·7	1·3	2·5	
90	75	0·242	0·022	20	2500	1·1	3·5	6·3	12·3	59B/U

All the above cables have solid dielectric with a velocity factor of 0·66 with the exception of those marked with an asterisk which are helical membrane and have a velocity factor of 0·96.

WAVEGUIDE SIZES

Frequency (GHz)	Wavelength (cm)	WG Internal dimensions (in.)	WG Internal dimensions (cm)	RCSC British WG No.	British Inter-Services Ref. No.		EIA WR ( )	IEC R ( )	NATO NWG (1 or 2)*	JAN Type RG ( )			Cut-off Frequency
					Brass 70/30	Aluminium				Copper or brass	Aluminium	Silver	
0·32–0·49	93·68–61·18	23·80×11·5	58·420×29·210	00			2300	3	01				0·265
0·35–0·53	85·65–56·56	21·0 ×10·5	53·34 ×26·670	0			2100	4	02				0·281
0·41–0·625	73·11–47·96	18·0 ×9·0	45·72 ×22·86	1			1800	5	03		201		0·328
0·49–0·75	61·18–39·97	15·0 ×7·5	38·1 ×19·65	2			1500	6	04		202		0·393
0·64–0·96	46·84–31·23	11·5 ×5·75	29·210×14·605	3			1150	8	05		203		0·513
0·75–1·12	39·95–26·76	9·75 ×4·875	24·765×12·3825	4			975	9	06		204		0·605
0·96–1·45	31·23–20·67	7·7 ×3·85	19·558×9·779	5			770	12	07		205		0·766
1·12–1·70	26·76–17·63	6·5 ×3·25	16·510×8·255	6		012–0037	650	14	08	69	103		0·908
1·45–2·20	20·67–13·62	5·1 ×2·55	12·954×6·477	7			510	18	09				1·157
1·70–2·60	17·63–11·53	4·3 ×2·15	10·922×5·461	8	083–0144	083–0144	430	22	10	104	105		1·372
2·20–3·30	13·63–9·08	3·4 ×1·7	8·636 ×4·318	9A	012–0040	012–0042	340	26	11	112	113		1·763
2·60–3·95	11·53–7·59	2·84 ×1·34	7·2163×3·403	10	083–0068	083–0069	284	32	12	48	75		2·078
3·30–4·90	9·08 –6·12	2·29 ×1·145	5·8166×2·909	11A	012–0045	012–0047	229	40	13				2·577
3·95–5·85	7·95 –5·12	1·872×0·872	4·7549×2·2149	12	083–0077	083–0078	187	48	14	49	95		3·152
4·90–7·05	6·12 –4·25	1·59 ×0·795	4·0486×2·0193	13	083–0146	083–0147	159	58	15				3·711
5·85–8·20	5·12 –3·66	1·372×0·622	3·4849×1·58	14	083–0081	083–0082	137	70	16	50	106		4·301
7·05–10·00	4·25 –2·99	1·122×0·497	2·880 ×1·2624	15	083–0086	083–0087	112	84	17	51	68		5·259
8·20–12·40	3·66 –2·42	0·90 ×0·40	2·286 ×1·016	16	083–0097	083–0099	90	100	18	52	67		6·557
10·00–15·00	2·99 –2·00	0·75 ×0·375	1·9050×0·9525	17			75	120	19				2·868
12·40–18·00	2·42 –1·66	0·622×0·311	1·58 ×0·790	18	083–0101		62	140	20	91		107	9·426
15·00–22·00	2·00 –1·36	0·510×0·255	1·295 ×0·6477	19			51	180	21				11·574
18·00–26·50	1·66 –1·13	0·420×0·170	1·0668×0·4318	20	Precision		42	220	22	53	121	66	14·047
22·00–33·00	1·36 –0·91	0·340×0·170	0·8636×0·4318	21			34	260	23				17·328
26·50–40·00	1·13 –0·75	0·280×0·140	0·7112×0·3556	22	083–1500		28	320	24			96	21·081
33·00–50·00	0·91 –0·60	0·224×0·112	0·5659×0·2845	23	083–1501		22	400	25			97	26·342
40·00–60·00	0·75 –0·50	0·188×0·94	0·4775×0·2388	24	083–1502		19	500	26				31·357
50·00–75·00	0·60 –0·40	0·148×0·074	0·3759×0·1880	25	083–1503		15	620	27			98	39·863
60·00–90·00	0·50 –0·33	0·122×0·061	0·3098×0·1550	26	083–1504		12	740	28			99	48·350
75·00–10·00	0·40 –0·27	0·100×0·050	0·2540×0·1270	27	083–1505		10	900	29				59·010
90·00–140·0	0·33 –0·22	0·080×0·040	0·2032×0·1016	28	083–1506		8	1200	30				73·80
140·00–220·0	0·22 –0·14	0·051×0·025	0·1295×0·0635										116·80

* *N.B.*—(1) Aluminium. (2) Copper based alloy.

The cut-off wavelength of a rectangular waveguide, the wide dimension of which is *a* cm is given by $\lambda_{co} = 2a$

For a waveguide $$\frac{1}{\lambda^2} + \frac{1}{\lambda_{co}^2} = \frac{1}{\lambda_o^2}$$

where λ = waveguide wavelength, λ_{co} = waveguide cut-off wavelength, and λ_o = free space wavelength.

R.F. CABLES (US RG SERIES)

Cable No.	Nominal Impedance Z_0 (ohms)	Cable Outside Diameter	Velocity Factor	Approximate Attenuation (db per 100 ft.)					Capacity pF/ft.	Maximum Operating Voltage RMS
				1 MHz	10 MHz	100 MHz	1000 MHz	3000 MHz		
RG-5/U	52·5	0·332 in.	0·659	0·21	0·77	2·9	11·5	22·0	28·5	3000
RG-5B/U	50·0	0·332 in.	0·659	0·16	0·66	2·4	8·8	16·7	29·5	3000
RG-6A/U	75·0	0·332 in.	0·659	0·21	0·78	2·9	11·2	21·0	20·0	2700
RG-8A/U	50·0	0·405 in.	0·659	0·16	0·55	2·0	8·0	16·5	30·5	4000
RG-9/U	51·0	0·420 in.	0·659	0·16	0·57	2·0	7·3	15·5	30·0	4000
RG-9B/U	50·0	0·425 in.	0·659	0·175	0·61	2·1	9·0	18·0	30·5	4000
RG-10A/U	50·0	0·475 in.	0·659	0·16	0·55	2·0	8·0	16·5	30·5	4000
RG-11A/U	75·0	0·405 in.	0·66	0·18	0·7	2·3	7·8	16·5	20·5	5000
RG-12A/U	75·0	0·475 in.	0·659	0·18	0·66	2·3	8·0	16·5	20·5	4000
RG-13A/U	75·0	0·425	0·659	0·18	0·66	2·3	8·0	16·5	20·5	4000
RG-14A/U	50·0	0·545	0·659	0·12	0·41	1·4	5·5	12·0	30·0	5500
RG-16/U	52·0	0·630 in.	0·670	0·1	0·4	1·2	6·7	16·0	29·5	6000
RG-17A/U	50·0	0·870 in.	0·659	0·066	0·225	0·80	3·4	8·5	30·0	11000
RG-18A/U	50·0	0·945	0·659	0·066	0·225	0·80	3·4	8·5	30·5	11000
RG-19A/U	50·0	1·120 in.	0·659	0·04	0·17	0·68	3·5	7·7	30·5	14000
RG-20A/U	50·0	1·195 in.	0·659	0·04	0·17	0·68	3·5	7·7	30·5	14000

RG-21/AU	50·0	0·332 in.	0·659	1·4	4·4	13·0	43·0	85·0	30·0	2700
RG-29/U	53·5	0·184 in.	0·659	0·33	1·2	4·4	16·0	30·0	28·5	1900
RG-34A/U	75·0	0·630 in.	0·659	0·065	0·29	1·3	6·0	12·5	20·5	5200
RG-34B/U	75	0·630 in.	0·66		0·3	1·4	5·8		21·5	6500
RG-35A/U	75·0	0·945 in.	0·659	0·07	0·235	0·85	3·5	8·60	20·5	10000
RG-54A/U	58·0	0·250	0·659	0·18	0·74	3·1	11·5	21·5	26·5	3000
RG-55/U	53·5	0·206 in.	0·659	0·36	1·3	4·8	17·0	32·0	28·5	1900
RG-55A/U	50·0	0·216 in.	0·659	0·36	1·3	4·8	17·0	32·0	29·5	1900
RG-58/U	53·5	0·195 in.	0·659	0·33	1·25	4·65	17·5	37·5	28·5	1900
RG-58C/U	50·0	0·195 in.	0·659	0·42	1·4	4·9	24·0	45·0	30·0	1900
RG-59A/U	75·0	0·242 in.	0·659	0·34	1·10	3·40	12.·0	26·0	20·5	2300
RG-59B/U	75	0·242	0·66		1·1	3·4	12		21	2300
RG-62A/U	93·0	0·242 in.	0·84	0·25	0·85	2·70	8·6	18·5	13·5	750
RG-74A/U	50·0	0·615 in.	0·659	0·10	0·38	1·5	6·0	11·5	30·0	5500
RG-83/U	35·0	0·405 in.	0·66	0·23	0·80	2·8	9·6	24·0	44·0	2000
*RG-213/U	50	0·405	0·66	0·16	0·6	1·9	8·0		29·5	5000
†RG-218/U	50	0·870	0·66	0·066	0·2	1·0	4·4		29·5	11000
‡RG-220/U	50	1·120	0·66	0·04	0·2	0·7	3·6		29·5	14000

* Formerly RG8A/U † Formerly RG17A/U ‡ Formerly RG19A/U

AERIALS

RESONANT LENGTHS OF HALF-WAVE DIPOLES

(Wavelength / Diameter)	(Value of Dipole length / Wavelength for resonance)	Feed Impedance (Ohms)
50	0·458	60·5
100	0·465	61·0
200	0·471	61·6
400	0·475	63·6
1,000	0·479	65·3
4,000	0·484	67·2
10,000	0·486	68·1
100,000	0·489	69·2

The dimensions used in calculating the ratios must be in similar units (e.g. both in metres or both in centimetres).

From *Aerials for Metre and Decimetre Wavelengths* by R. A. Smith.

V AND RHOMBIC AERIALS

Leg Length	Angle A	Gain V Aerial	Gain Rhombic
1 λ	90	3db	6db
2 λ	72	4½db	7½db
3 λ	60	6db	9db
4 λ	50	7db	10db
5 λ	45	8db	11db
6 λ	40	9db	12db

Average design figures for V and rhombic aerials. The angle A is the apex angle.

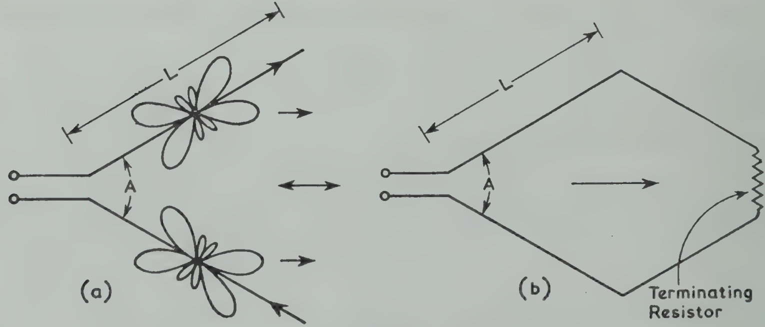


Fig. 50. V and rhombic aerials. The diagram on the left (a) shows how the main lobes of two long wire radiators are added to form the main beam. The apex angle A is given in the table above.

TYPICAL DIMENSIONS OF YAGI ARRAYS

Element	Element Length / Wavelength	Length of Elements		
		70·3 MHz	145 MHz	435 MHz
Reflector ...	0·495	$83\frac{1}{2}$ in.	40 in.	$13\frac{1}{2}$ in.
Dipole radiator ...	0·473	$79\frac{1}{2}$ in.	$38\frac{1}{2}$ in.	$12\frac{7}{8}$ in.
Director D1 ...	0·440	74 in.	36 in.	12 in.
Director D2 ...	0·435	$73\frac{1}{4}$ in.	$35\frac{1}{2}$ in.	$11\frac{7}{8}$ in.
Director D3 ...	0·430	$72\frac{1}{2}$ in.	35 in.	$11\frac{3}{4}$ in.
Succeeding directors	0·005 successively	$71\frac{3}{4}$, etc.	$34\frac{1}{2}$, etc.	$11\frac{1}{2}$, etc.
End director ...	0·007 less than penultimate director	1 in. less	$\frac{3}{4}$ in. less	$\frac{3}{8}$ in. less

Elements	Element Spacing / Wavelength	Spacing Between Elements		
		70·3 MHz	145 MHz	435 MHz
Reflector/Radiator	0·125	21 in.	$10\frac{1}{4}$ in.	$3\frac{3}{8}$ in.
Radiator/Director D1	0·125	21 in.	$10\frac{1}{4}$ in.	$3\frac{3}{8}$ in.
D1—D2	0·25	42 in.	$20\frac{1}{2}$ in.	$6\frac{3}{4}$ in.
D2—D3, etc. ...	0·25	42 in.	$20\frac{1}{2}$ in.	$6\frac{3}{4}$ in.

These dimensions are correct only for elements having diameters in the following ranges:

70·3 MHz	145 MHz	435 MHz
$\frac{1}{2}$—$\frac{3}{4}$ in.	$\frac{1}{4}$—$\frac{3}{8}$ in.	$\frac{1}{8}$—$\frac{3}{16}$ in.

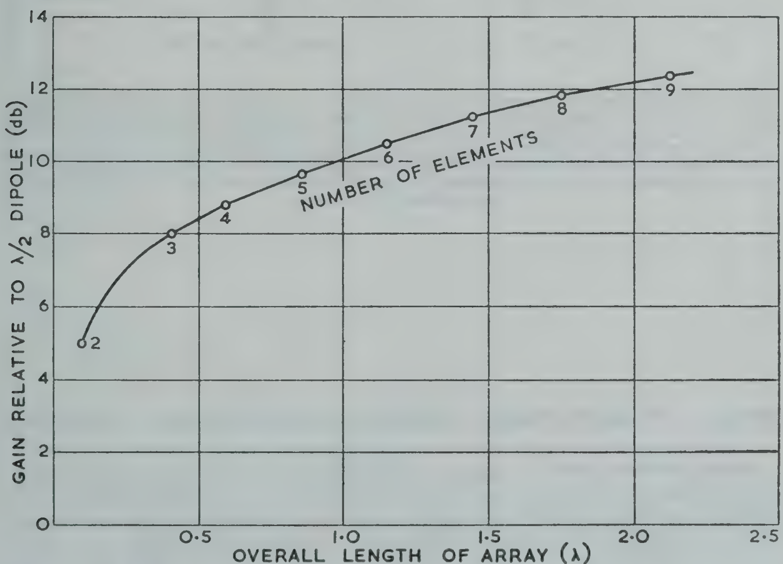


Fig. 51.
The gain of a Yagi array increases as the number of elements increases. In the graph "2 elements" signifies radiator-plus-reflector: "3 elements" therefore implies one director, and so on. The length of the array is expressed in units of wavelength. The curve shown here is due to S. Kharbanda, G2PU

(Courtesy Labgear Ltd.)

YAGI DESIGN CHART

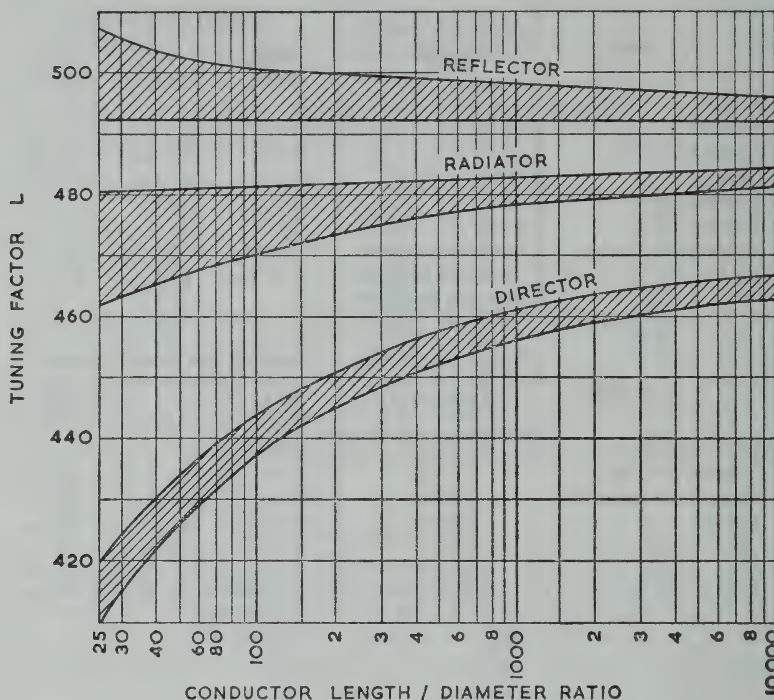


Fig. 52.

Design chart for Yagi arrays, giving element lengths as a function of conductor length-to-diameter ratio. The tuning factor L is divided by the frequency in MHz to give the lengths in feet. These curves are for arrays of overall length 0·3λ, with reflector reactance +40 to +60 ohms and director −30 to −40 ohms, and give arrays of input impedance between 15 and 20 ohms. Element lengths which fall within the shaded areas will give an array which can be used without further adjustment, though the front-to-back ratio may be improved by adjusting the reflector.

EFFECT OF AMPLITUDE MODULATION ON AERIAL CURRENT

Depth of Modulation (per cent)	Ratio: $\frac{\text{a.f. power}}{\text{d.c. power of p.a.}}$	Increase in Aerial Current (per cent)
100	0·5	22·6
90	0·405	18·5
80	0·32	15·1
70	0·245	11·5
60	0·18	8·6
50	0·125	6·0

FOLDED DIPOLE CALCULATIONS

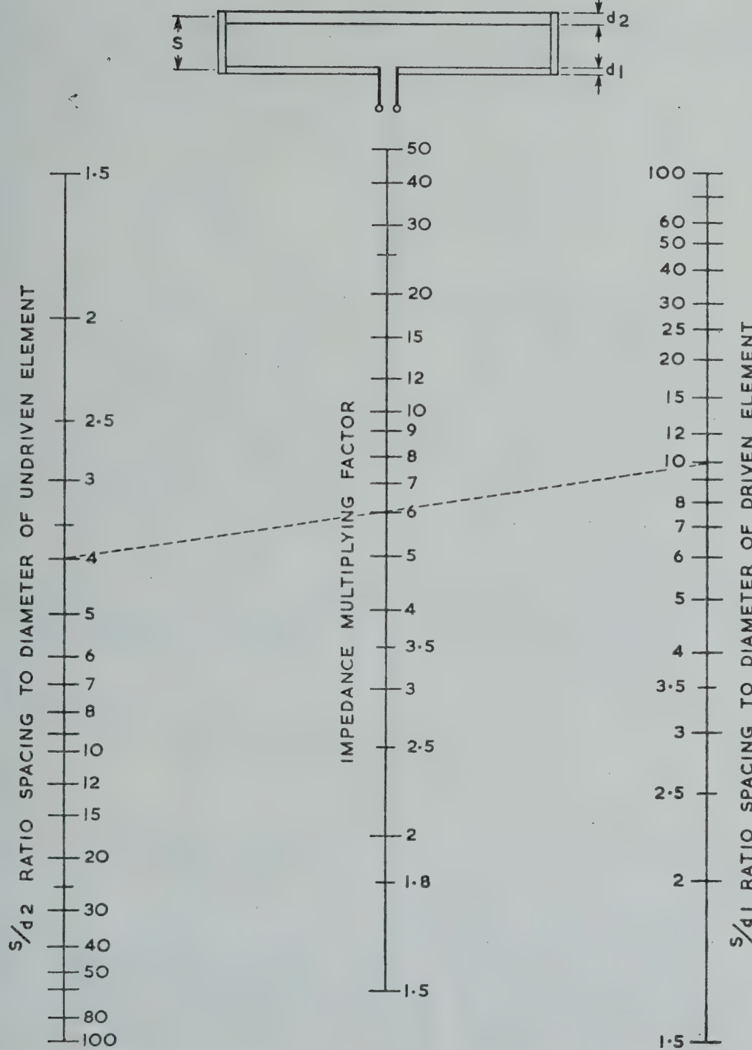


Fig. 53.

Nomogram for folded dipole calculations. The impedance multiplying factor depends on the two ratios of conductor diameter to spacing between centres, and is always 4 : 1 when the diameters are equal. A ruler laid across the scales will give pairs of spacing/diameter ratios for any required multiplier. In the example shown the driven element diameter is one-tenth of the spacing and the other element diameter one-quarter of the spacing, resulting in a step up of 6 : 1. There is an unlimited number of solutions for any given ratio. The chart may also be used to find the step-up ratio of an aerial of given dimensions.

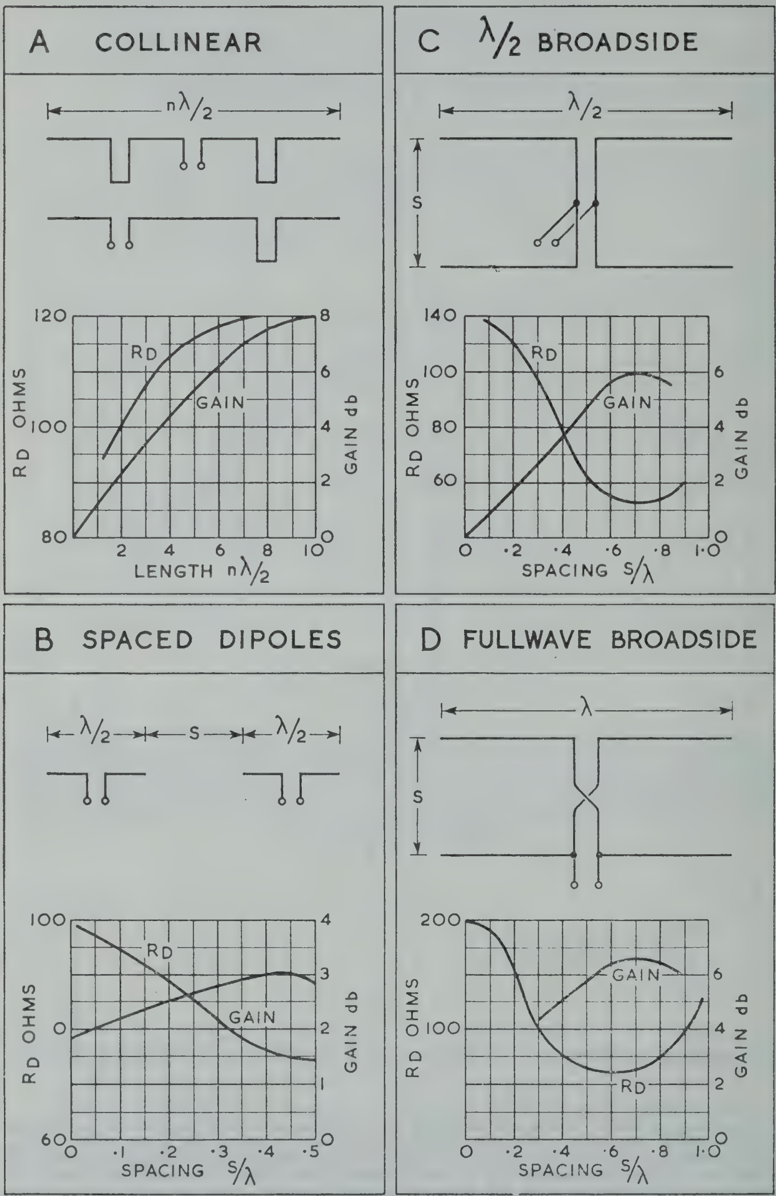
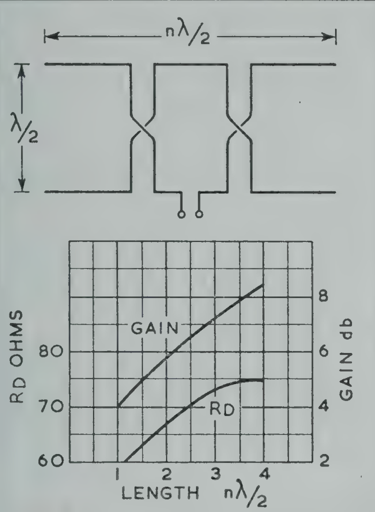


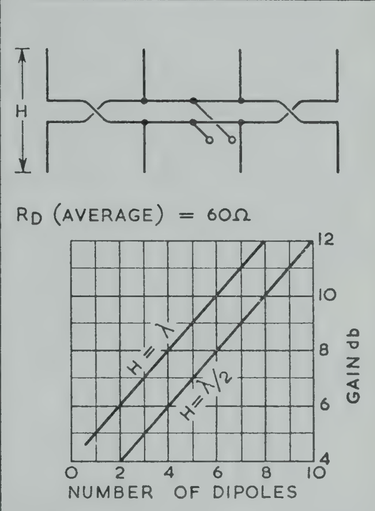
Fig. 54.

General types of broadside array. (a) Collinear arrays; (b) End-spaced dipoles; (c, d, e) Two-tier, Sterba or Barrage arrays; (f) Pine Tree or Koomans, stacked horizontal λ/2 or λ dipoles, (g, h) Vertically polarized broadside arrays. Gain figures are with reference to a free-space dipole, in terms of spacing or total length in half-waves. Resistance figures

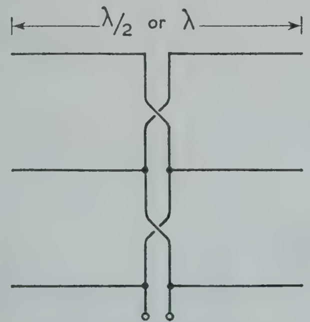
E $n\lambda/2$ STERBA



G VERTICAL BROADSIDE

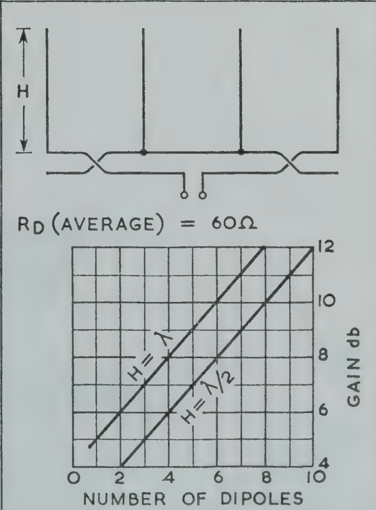


F VERTICAL STACK



FOR CURVES
SEE G & H

H VERTICAL BROADSIDE (END-FED)



are average over the array, and are added in series or parallel according to the feed arrangements. The aerial in (c) can be arranged to give a broadside beam over a 2 : 1 frequency range, e.g. 14, 21 and 28 MHz.

MODULATION DEPTH

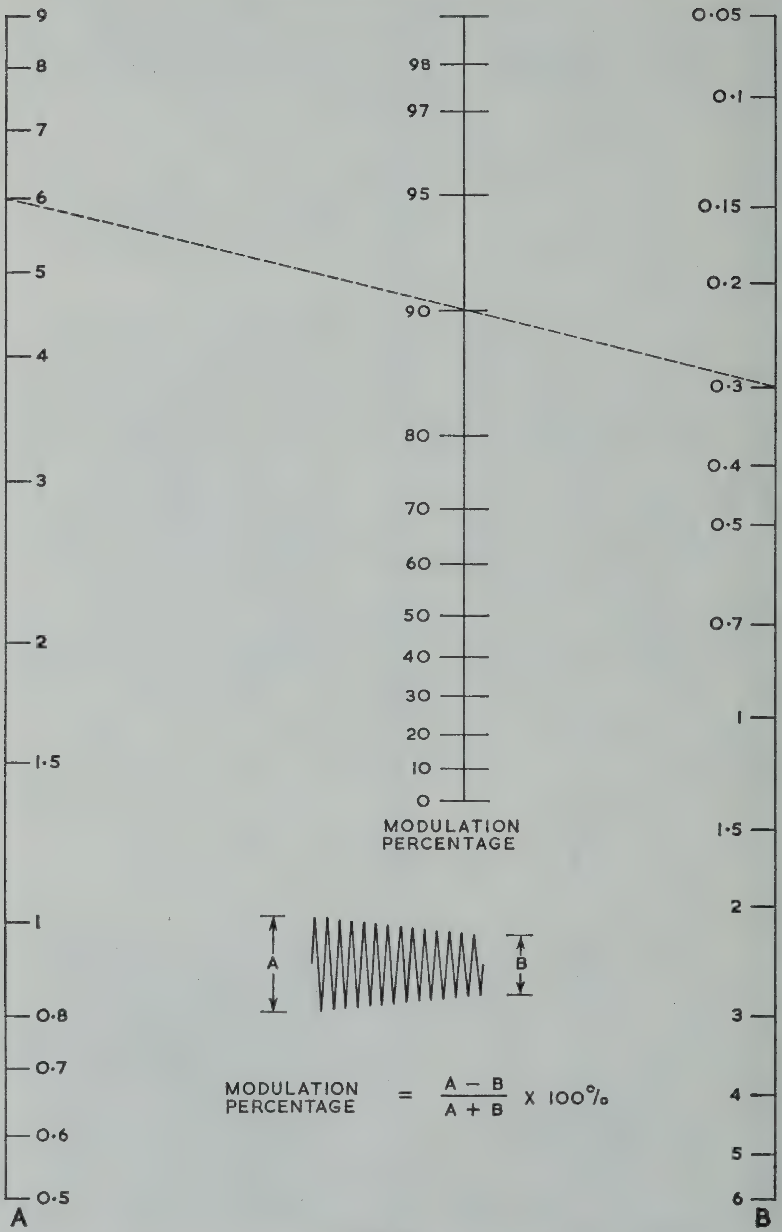


Fig. 55.

Abac for the calculation of modulation depth from the trapezoidal pattern. The dotted line illustrates an example in which the large side (A) is 6 units long and the shorter one, (B) 0·3 unit indicating a depth of modulation of just over 90 per cent.

MODULATION TRANSFORMER RATIOS

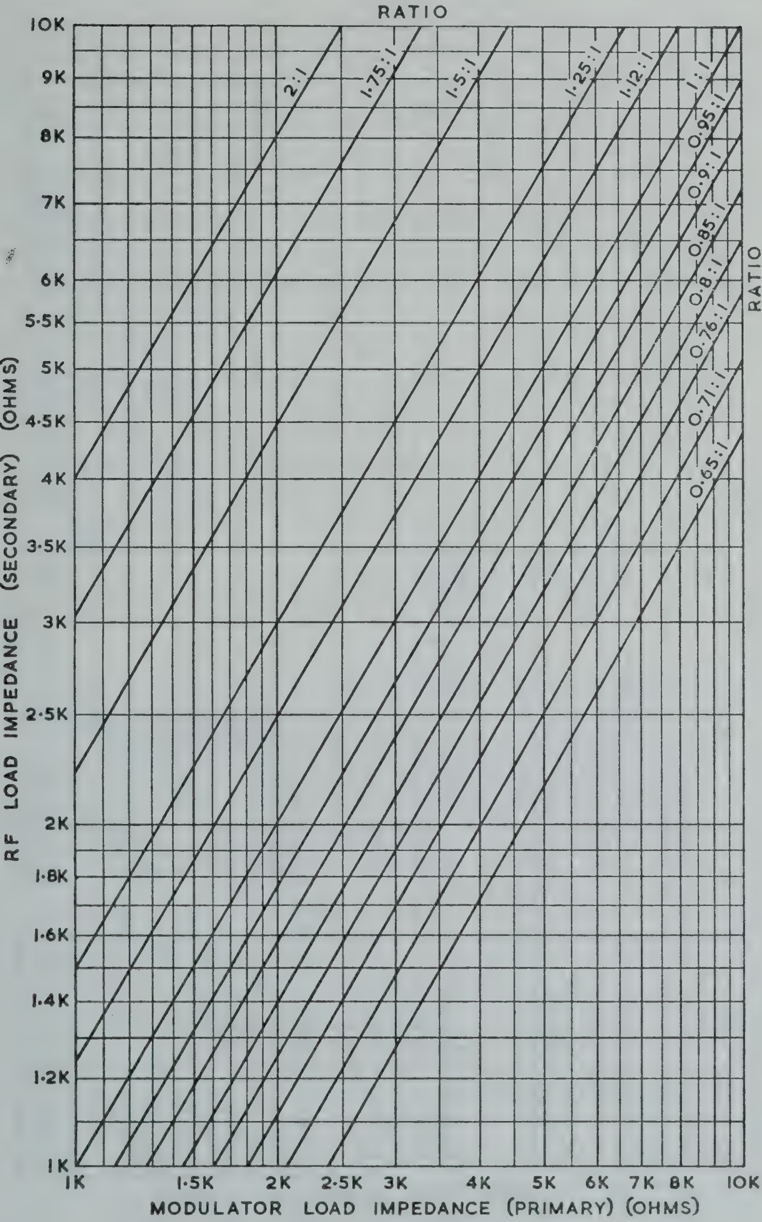


Fig. 56.

OUTPUT TRANSFORMER RATIOS

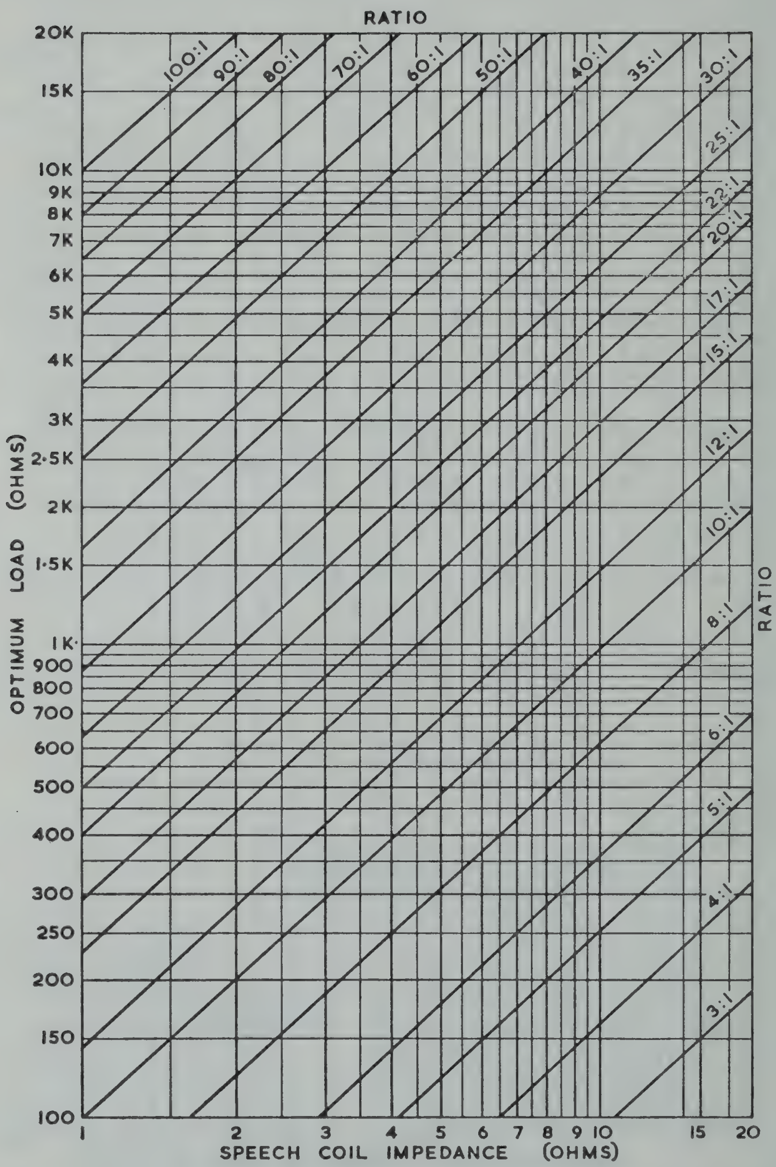


Fig. 57.

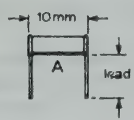
I.F. TRANSFORMERS

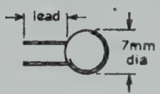
Capacitance (To nearest pF) for Resonance for S.S.B. Filters

L	Frequency in kHz										
mH	400	410	420	430	440	450	460	470	480	490	500
1	158	151	144	137	131	125	120	115	110	105	101
1·1	144	137	131	125	119	114	109	104	100	96	92
1·2	132	126	120	114	109	104	100	96	91	88	84
1·3	122	115	111	105	101	96	92	88	85	81	78
1·4	113	108	103	98	93	89	85	82	79	75	72
1·5	106	100	96	91	87	83	80	76	73	70	68
1·6	99	94	90	86	82	78	75	72	69	66	63
1·7	93	89	84	81	77	74	70	67	65	62	60
1·8	88	84	80	76	73	69	66	64	61	59	56
1·9	83	79	76	72	69	66	63	60	58	56	53
2·0	79	75	73	69	65	63	60	57	55	53	51

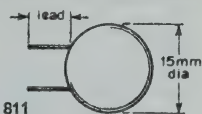
SELF-RESONANT FREQUENCIES OF TYPICAL CAPACITORS

Capacitance (pF)	Frequency in MHz with $\frac{1}{4}$ in. leads	Frequency in MHz with $\frac{1}{2}$ in. leads	ERIE Type
330	85	62	831
220	120	82	831
100	145	120	831
47	240	180	831
33	250	210	831
22	280	235	831
15	400	300	831
10	530	390	831
6·8	600	470	831
1000	75	42	





Capacitance (pF)	Frequency in MHz with $\frac{1}{4}$ in. leads	Frequency in MHz with $\frac{1}{2}$ in. leads	ERIE Type
10,000	14	12	811
1000 (feed through) (18 swg single lead)	—	40	701B
1000 (discoidal) (18 swg single lead)	200	125	CDFT 100-107



VOLTAGE AND POWER RATIOS IN DECIBELS

Voltage	Power	db	Voltage	Power
1·0	1·0	0	1·0	1·0
0·9883	0·9772	0·1	1·012	1·022
0·9777	0·9551	0·2	1·023	1·047
0·9661	0·9328	0·3	1·032	1·072
0·9551	0·9120	0·4	1·047	1·097
0·9442	0·8914	0·5	1·059	1·122
0·9328	0·8711	0·6	1·072	1·148
0·9223	0·8509	0·7	1·084	1·175
0·9120	0·8320	0·8	1·097	1·202
0·9023	0·8130	0·9	1·109	1·230
0·8914	0·7942	1·0	1·122	1·259
0·8711	0·7590	1·2	1·148	1·318
0·8505	0·7246	1·4	1·175	1·380
0·8320	0·6920	1·6	1·202	1·445
0·8130	0·6606	1·8	1·230	1·514
0·7942	0·6308	2·0	1·259	1·585
0·7762	0·6024	2·2	1·288	1·660
0·7590	0·5754	2·4	1·318	1·733
0·7414	0·5494	2·6	1·349	1·820
0·7246	0·5247	2·8	1·380	1·906
0·7078	0·5012	3·0	1·413	1·995
0·6682	0·4466	3·5	1·496	2·239
0·6308	0·3981	4·0	1·585	2·512
0·5955	0·3549	4·5	1·679	2·818
0·5624	0·3162	5·0	1·778	3·162
0·5307	0·2819	5·5	1·884	3·548

Voltage	Power	db	Voltage	Power
0·5012	0·2512	6·0	1·995	3·981
0·4467	0·1995	7·0	2·239	5·012
0·3981	0·1585	8·0	2·512	6·310
0·3548	0·1259	9·0	2·818	7·943
0·3162	0·1000	10	3·162	10·000
0·2818	0·07943	11	3·549	12·59
0·2512	0·06310	12	3·981	15·85
0·2239	0·05012	13	4·467	19·95
0·1995	0·03981	14	5·012	25·12
0·1778	0·03162	15	5·623	31·62
0·1585	0·02512	16	6·310	39·81
0·1413	0·01995	17	7·079	50·12
0·1259	0·01585	18	7·943	63·10
0·1122	0·01259	19	8·913	79·43
0·1000	0·01000	20	10·000	100·00
0·056	0·00316	25	17·78	316·2
0·03162	0·001	30	31·62	1,000
0·01778	0·000316	35	56·23	3,162
0·010	0·0001	40	100·0	10,000
0·0056	0·0000316	45	177·8	31,620
0·003162	0·00001	50	316·2	100,000
0·001	10^{-6}	60	1,000	10^{6}
0·0003162	10^{-7}	70	3,162	10^{7}
0·0001	10^{-8}	80	10,000	10^{8}
0·00003162	10^{-9}	90	31,620	10^{9}
0·00001	10^{-10}	100	100,000	10^{10}

WINDING COILS ON STANDARD FORMERS

Coil formers of the Aladdin type are widely used in modern radio equipment. Two charts have been prepared to enable calculation of the necessary winding data to be made quickly and easily.

Use of Fig. 58

The use of Fig. 58 on page 71 is best illustrated by describing a typical calculation.

Example: It is required to wind a coil on an Aladdin type F804 ($\frac{7}{16}$ in. diameter) former which will resonate at 7 MHz with a 50 pF capacitor.

The method is as follows:

1. Draw a straight line through 50 pF (axis *A*) and 7 MHz (axis *B*).
2. Project the line to cut axis *C* and read off the required inductance, which in this case is 10·3 μH.
3. Draw a horizontal line through 10·3 μH on axis *D* and a vertical line through a reasonable winding length (say 0·5 in.) and determine the most suitable wire gauge to use, i.e., 32 s.w.g.
4. From the 32 s.w.g. curve determine the exact winding length to give an inductance of 10·3 μH, i.e. 0·48 in.

The coil required will therefore be close wound with 32 s.w.g. enamelled copper wire and 0·48 in. long.

If desired, the number of turns may be calculated using wire tables from which it will be found that the turns per inch for 32 s.w.g. enamelled copper wire is 83. Hence, a winding 0·48 in. long will consist of $(83 \times 0{\cdot}48) = 39{\cdot}8$ turns.

The following table, prepared from information provided by the London Electric Wire Company, shows the minimum turns per in. for enamelled copper wire of the gauges most commonly used by amateurs.

Gauge	Turns	Gauge	Turns
20 s.w.g.	26 t.p.i.	32 s.w.g.	82·6 t.p.i.
22 s.w.g.	33 t.p.i.	34 s.w.g.	96.2 t.p.i.
24 s.w.g.	41·5 t.p.i.	36 s.w.g.	116.3 t.p.i.
26 s.w.g.	50·3 t.p.i.	38 s.w.g.	144·9 t.p.i.
28 s.w.g.	61 t.p.i.	40 s.w.g.	178·6 t.p.i.
30 s.w.g.	72·5 t.p.i.	42 s.w.g.	212 t.p.i.

For coils of low inductance, i.e. less than 1 μH, it is advisable to space wind rather than close wind with a heavy gauge wire. Curves are, therefore, given in Fig. 58 for pitches of 10, 15 and 20 turns per inch using 26 s.w.g. enamelled copper wire. Other gauges may be used, however, without introducing significant errors.

The values shown in Fig. 58 for Aladdin F804 formers have been calculated for formers without cores. The variation in inductance obtainable with dust-iron or brass cores depends on the winding length and composition of the core material and no simple correction factor may be quoted. However, for coils between 0·3 and 0·8 in. long a dust-iron core will give a maximum possible inductance of about twice the "core-less" inductance, and a brass core a minimum possible inductance of about 0·8 times the "core-less" inductance. These factors should be borne in mind when designing variable inductances from the charts.

Use of Fig. 59

The inductance required is found from Fig. 58 in the same way as for Aladdin F804 formers and the winding details determined from Fig. 59. Measurements show that the effect of a screening can on the average coil wound on 0·3 in. diameter formers is to reduce the inductance by about 5 per cent. When designing very low inductance coils, an allowance of approximately 0·15 μH should be made for the leads.

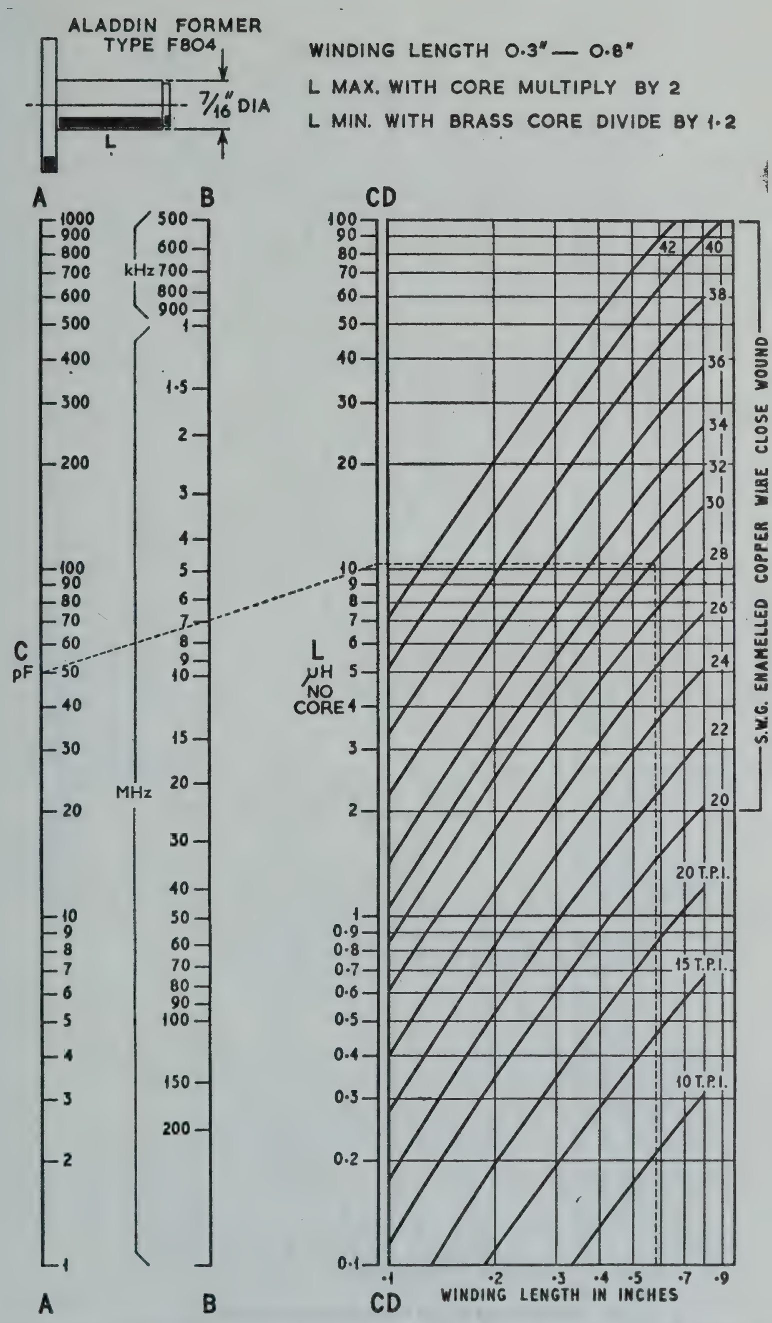


Fig. 58. The calculation of inductance required and winding data for Aladdin type F804 coil formers. The dashed lines refer to the worked example.

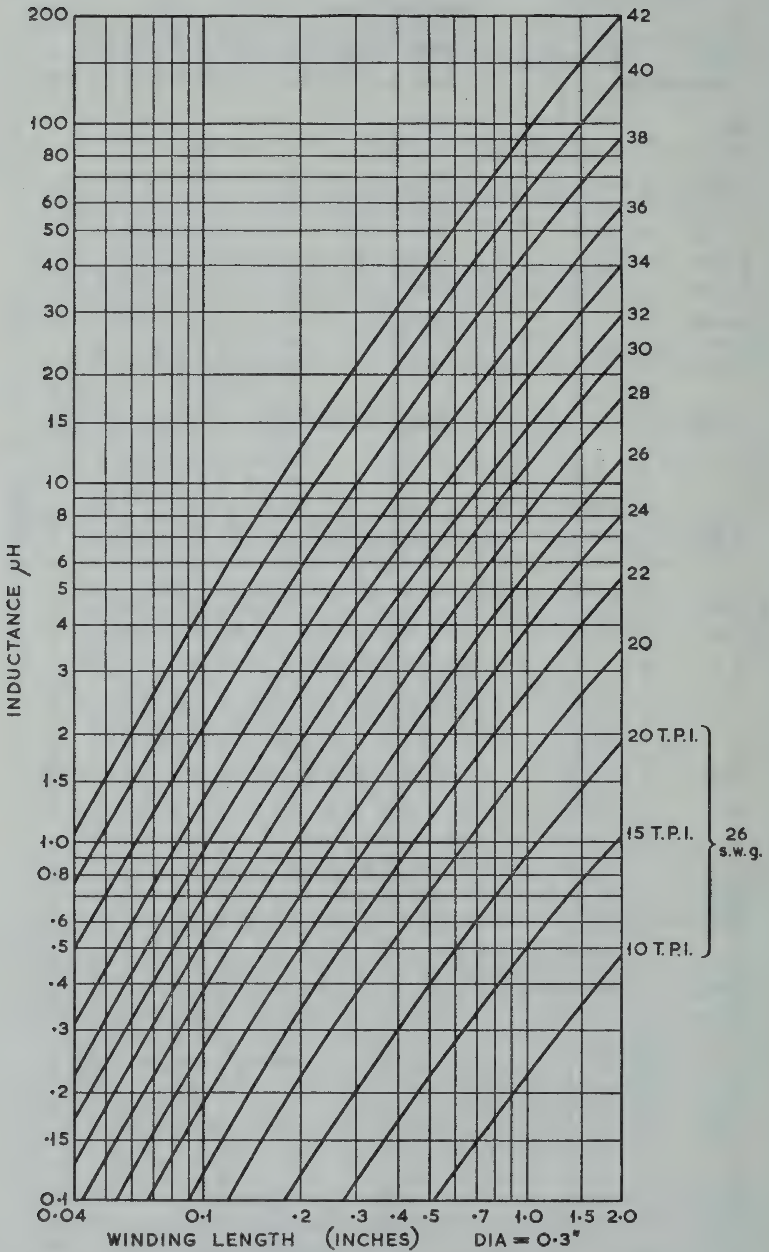


Fig. 59. Winding data for 0·3 in. diameter coil forms.

BRITISH STANDARD COPPER WIRE TABLE

S.W.G.	Diameter (inches)	Resistance (*a*)	Length (*b*)	Current rating (c)	Turns per linear inch					Turns per square inch					Nearest American wire gauge
					Enamel	Single Silk	Double silk	Single cotton	Double cotton	Enamel	Single silk	Double silk	Single cotton	Double cotton	
10	0·128	1·866	6·67	15·442	7·48	—	—	7·35	7·0	56	—	—	54	49	10
12	0·104	2·826	10·23	10·194	9·09	—	—	8·8	8·4	82·6	—	—	77·4	70·6	12
14	0·080	7·776	17·16	6·032	11·78	—	—	11·2	10·5	139	—	—	125·4	110	14
16	0·064	7·463	26·86	3·86	14·8	14·7	14·5	13·9	12·0	219	216	210	193·2	169	16
18	0·048	13·27	47·66	2·1715	19·7	19·8	19·4	18·0	16·8	388	392	376	324	282	19
20	0·036	23·59	85·00	1·2215	26·0	26·0	25·3	23·5	21·0	676	676	640	552	441	21
22	0·028	38·99	140·6	0·73	33·0	33·0	31·9	29·1	25·4	1089	1089	1018	847	645	23
24	0·022	63·16	228·3	0·4561	41·6	42·1	40·0	36·7	31·0	1731	1772	1600	1347	961	25
26	0·018	94·4	340·0	0·3054	50·2	51·2	48·3	43·0	35·4	2520	2621	2333	1849	1253	27
28	0·0148	139·6	503·0	0·2064	61·0	61·7	57·4	50·2	38·6	3721	3807	3295	2520	1490	28
30	0·0124	199	716·6	0·1450	72·5	72·4	66·6	57·1	44·4	5256	5242	4436	3260	1971	29
32	0·0108	262	943·3	0·1099	82·7	81·9	74·6	62·8	47·8	6839	6708	5565	3944	2285	31
34	0·0092	361	1300	0·0798	97	94·3	84·7	69·9	51·7	9409	8892	7174	4886	2673	32
36	0·0076	529	1903	0·0545	116	111	97·9	85·4	59·9	13456	12321	9584	7293	3588	34
38	0·0060	849	3056	0·0340	145	135	113	99	67·7	21025	18225	12769	9801	4583	36
40	0·0048	1327	4766	0·0217	178	161	131	112	75·1	31684	25921	17161	12544	5640	38

(*a*) Ohms per 1000 yards at 60°F; (*b*) Yards per lb.; (c) Amps at 1200 amps per square inch.

CURRENT RATINGS FOR RUBBER, P.V.C. AND POLYTHENE INSULATED CABLES

(Subject to Voltage Drop)

SIZE OF CONDUCTOR					Cables bunched and enclosed in conduit, in free air or open trench				
					Rubber, P.V.C. or polythene insulated, including tough rubber, P.V.C., lead or aluminium sheathed.				
Nominal Area	No. and Diameter of Wires	Standard Weight of Conductor per 1000 yards	Diameter of Conductor	Maximum Allowable Resistance for Tinned Copper Wire at 20° C. (68° F.) per 1000 yards	2-single core	4-single core	3-single core or 4-single core	1-twin core	1-three core or 1-four core
					D.C. or 1-phase A.C.	D.C. or 1-phase A.C.	A.C. 3-phase	D.C. or 1-phase A.C.	A.C. 3-phase
1	2	3	4	5	6	7	8	9	10
Sq. in.	No./in.	Lb	In.	Ohms	Amps	Amps	Amps	Amps	Amps
00·015	1/·044	17·58	0·044	16·71	5	5	5	5	5
00·02	3/·029	23·37	0·062	13·08	10	10	10	10	8
0·003	3/·036	36·02	0·078	8·408	15	13	13	15	10
0·0045	7/·029	54·39	0·087	5·591	20	15	15	20	15
0·007	7/·036	83·81	0·108	3·593	28	22	25	28	20
0·010	7/·044	125·20	0·132	2·405	36	29	32	36	25
0·0145	7/·052	174·9	0·156	1·723	43	34	39	43	30
0·0225	7/·064	264·9	0·192	1·137	53	42	48	53	37
0·03	19/·044	340·4	0·220	0·8877	62	50	56	62	43
0·04	19/·052	475·5	0·260	0·6358	74	59	67	74	52
0·06	19/·064	720·3	0·320	0·4196	97	78	88	97	68

FLEXIBLE CORDS

All types to B.S.7 Rubber Insulated and B.S. 2004 P.V.C.

Conductor		Current rating (Subject to voltage drop) D.C. or single-phase or three-phase A.C.	Resistance* per 1000 yards at 20°C. 68°F.)	Maximum permissible weight supported by a twin cord (see Regulation 310 (A))
Nominal Area	No. and Diameter of Wires		Maximum Allowable Tinned Wires	
Sq. in.	No./in.	Amps	Ohms	Lb.
0·0006	14/·0076	2	42·03	3
0·001	23/·0076	5	25·57	5
0·0017	40/·0076	10	14·71	10
0·003	70/·0076	15	8·41	10
0·0048	110/·0076	20	5·35	10
0·007	162/·0076	25	3·63	10

* The figures given for resistance refer to straight single cores. Where the cores are twisted into twin- or multi-core cords, an allowance must be made for the extra length due to laying up.

FUSE WIRE TABLE

Fusing Current	Copper		Tin		Lead	
	Diam.	S.W.G.	Diam.	S.W.G.	Diam.	S.WG.
1 amp	0·0021	47	0·0072	37	0·0081	35
2 amps	0·0034	43	0·0113	31	0·0128	30
3 amps	0·0044	41	0·0149	28	0·0168	27
4 amps	0·0053	39	0·0181	26	0·0203	25
5 amps	0·0062	38	0·0210	25	0·0236	23
10 amps	0·0098	33	0·0334	21	0·0375	20
15 amps	0·0129	30	0·0437	19	0·0491	18
20 amps	0·0156	28	0·0529	17	0·0595	17

COMPARATIVE RESISTANCES OF SOME METALS

Material	Relative resistance
Copper	1·0
German Silver	11·7–18·5
Eureka	29·3
Nichrome	55
Silver	0·94
Aluminium	1·6
Brass	4·4
Nickel	4·3
Iron	6·1

RISE AND FALL OF VOLTAGE AND CURRENT

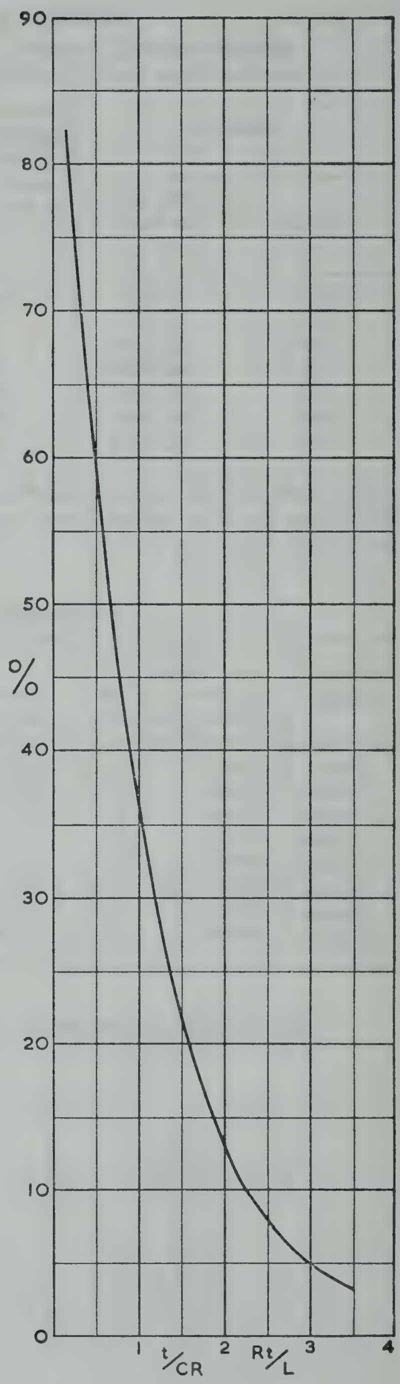


Fig. 60.

The time constant of a circuit having a capacitor or inductor in series with a resistor $t = CR$ or L/R and is the time required for the current or voltage to reach 63·2 per cent of its maximum value.

$$i = \frac{E}{R}\epsilon^{-\frac{tC}{R}}$$

$$i = \frac{E}{R}\epsilon^{-\frac{tR}{L}}$$

The graph enables either time or percentage of maximum voltage (or current) to be found. Example: a capacitor and a resistor have a time constant CR of 4 secs. If initially charged, what percentage of the charge-voltage will be retained after 8 secs.

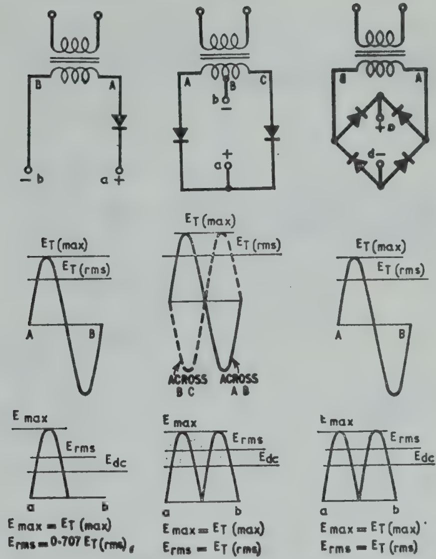
$$t/CR = 8/4 = 2$$

from the curve 2 = 14 per cent.

Conversely, in the same time the capacitor would be charged to 86 per cent of its maximum value, where t is in seconds, R in ohms, L in Henrys, C in Farads.

POWER RECTIFICATION

Half-wave	Centre-tapped full-wave	Full-wave bridge



		Half-wave	Centre-tapped full-wave	Full-wave bridge
Voltage Relationships				
Crest working voltage in terms of E_{dc}		3·14E_{dc}	3·14E_{dc}	1·57E_{dc}
Crest working voltage in terms of $E_{T(rms)}$		1·41$E_{T(rms)}$	2·82$E_{T(rms)}$	1·41$E_{T(rms)}$
E_{dc} in terms of r.m.s. input voltage per phase $E_{T(rms)}$		0·45$E_{T(rms)}$	0·90$E_{T(rms)}$	0·90$E_{T(rms)}$
E_{dc} in terms of r.m.s. output voltage E_{rms}		0·636E_{rms}	0·90E_{rms}	0·90E_{rms}
E_{dc} in terms of peak output voltage E_{max}		0·318E_{max}	0·636E_{max}	0·636E_{max}
Input voltage $E_{T(rms)}$ in terms of E_{dc}		2·22E_{dc}	1·11E_{dc}	1·11E_{dc}
R.m.s. output voltage E_{rms} in terms of E_{dc}		1·57E_{dc}	1·11E_{dc}	1·11E_{dc}
Peak output voltage E_{max} in terms of E_{dc}		3·14E_{dc}	1·57E_{dc}	1·57E_{dc}
Ripple				
Fundamental ripple frequency f_r		f	2f	2f
% ripple = $\frac{\text{r.m.s. fundamental ripple voltage} \times 100}{E_{dc}}$		111	47·2	47·2
Output Current				
Average current per rectifier leg $I_{F(av)}$		I_{dc}	0·5 I_{dc}	0·5 I_{dc}
I_{rms} per rectifier leg	R	1·57I_{dc}	0·785 I_{dc}	0·785 I_{dc}
	L		0·707 I_{dc}	0·707 I_{dc}
I_{pk} per rectifier leg	R	3·14I_{dc}	1·57 I_{dc}	1·57 I_{dc}
	L		I_{dc}	I_{dc}
Tranformer Ratings				
Secondary r.m.s. voltage per transformer leg $E_{T(rms)}$		2·22E_{dc}	1·11E_{dc} (to centre-tap)	1·11E_{dc}
Secondary r.m.s. current per transformer leg $I_{T(rms)}$	R	1·57 I_{dc}	0·785 I_{dc}	1·11 I_{dc}
	L		0·707 I_{dc}	I_{dc}
Secondary volt-amp VA_s	R	3·48E_{dc}.I_{dc}	1·74E_{dc}.I_{dc}	1·23E_{dc}.I_{dc}
	L		1·57E_{dc}.I_{dc}	1·11E_{dc}.I_{dc}
Secondary utility factor U_s	R	0·287	0·574	0·813
	L		0·636	0·90
Primary voltage per transformer leg (transformer ratio 1 : 1)		2·22E_{dc}	1·11E_{dc}	1·11E_{dc}
Primary current per transformer leg (transformer ratio 1 : 1)	R	1·57I_{dc}	1·11I_{dc}	1·11 I_{dc}
	L		I_{dc}	I_{dc}
Primary volt-amp VA_p	R	3·483dc.I_{dc}	1·23E_{dc}.I_{dc}	1·23E_{dc}.I_{dc}
	L		1·11E_{dc}.I_{dc}	1·11E_{dc}.I_{dc}
Primary utility factor U_p	R	0·287	0·823	0·813
	L		0·90	0·90

VOLTAGE MULTIPLIER CIRCUITS

HALF-WAVE VOLTAGE DOUBLER

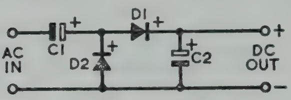


Fig. 61.

C1 = peak a.c. voltage
C2 = peak a.c. voltage × 2

BI-PHASE HALF WAVE OR FULL WAVE VOLTAGE DOUBLER

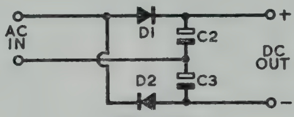


Fig. 62.

C2 and C3 = peak a.c. voltage

VOLTAGE TRIPLER

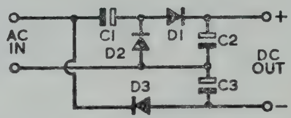


Fig. 63.

C1 = peak a.c. voltage
C2 = peak a.c. voltage
C3 = peak a.c. voltage × 2

VOLTAGE QUADRUPLER

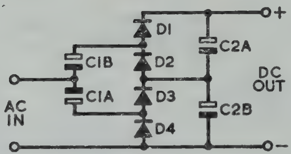


Fig. 64.

C1A = peak a.c. voltage
C1B = peak a.c. voltage × 3
C2A and C2B = peak a.c. voltage × 2
D1-D4 = peak a.c. voltage × 2

SEMICONDUCTOR POWER RECTIFIER DIODES

Surge Suppressors

Switching surges can be reduced by the inclusion of a series CR circuit across the primary or secondary of the power transformer or across the d.c. load circuit.

Typical component values may be calculated from:

$$C = \frac{70W}{V^2}\ \mu\text{F}$$

where W = power transformer rating in watts
V = r.m.s. voltage of the circuit concerned
R = five times the effective load resistance.

Voltage Sharing Resistors

Equalisation of the voltage across series connected diodes can be effected by connecting a resistor in parallel with each diode.

The value of the required resistors may be calculated from:

$$R = \frac{V}{KI}\ \text{ohms}$$

where V = p.i.v. rating of the diodes
I = maximum peak reverse current rating of the diodes
K = a constant depending on the number of diodes connected in series: two diodes, $K = 1$; three diodes, $K = 1{\cdot}2$; four diodes, $K = 1{\cdot}5$; five diodes, $K = 1{\cdot}7$; six diodes, $K = 2{\cdot}0$.

RIPPLE CHART

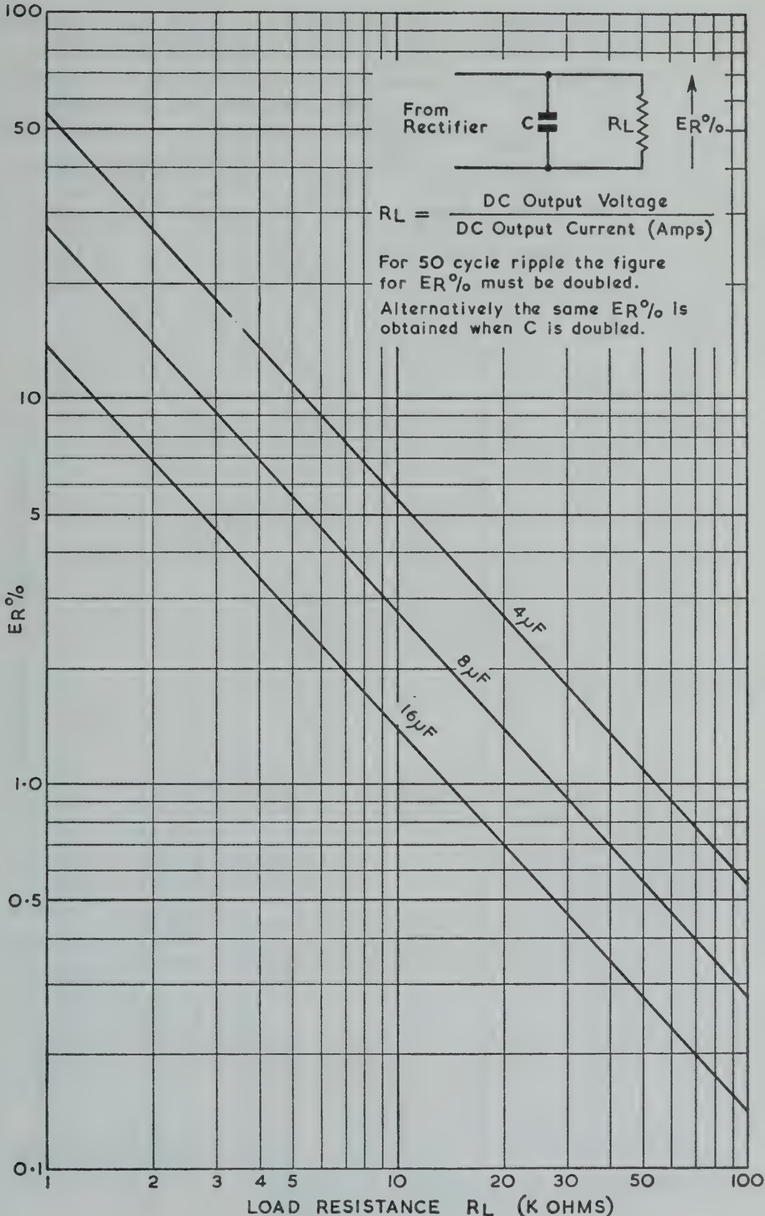


Fig. 65.

Curves showing 100 Hz ripple component as a percentage of the d.c. output voltage across a reservoir capacitor.

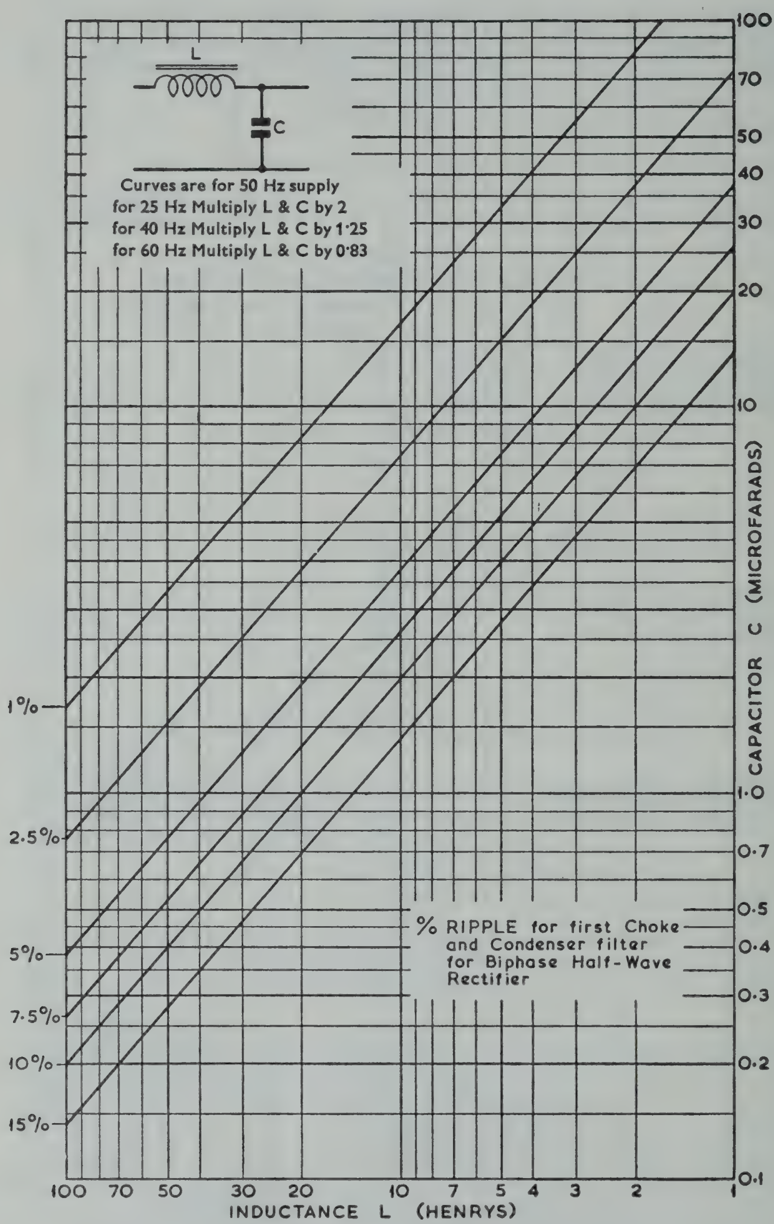

L
C
Curves are for 50 Hz supply
for 25 Hz Multiply L & C by 2
for 40 Hz Multiply L & C by 1·25
for 60 Hz Multiply L & C by 0·83
1%
2.5%
5%
7.5%
10%
15%
% RIPPLE for first Choke and Condenser filter for Biphase Half-Wave Rectifier
100
70
50
40
30
20
10
1·0
0·7
0·5
0·4
0·3
0·2
0·1
CAPACITOR C (MICROFARADS)
100 70 50 30 20 10 7 5 4 3 2 1
INDUCTANCE L (HENRYS)

Fig. 66.

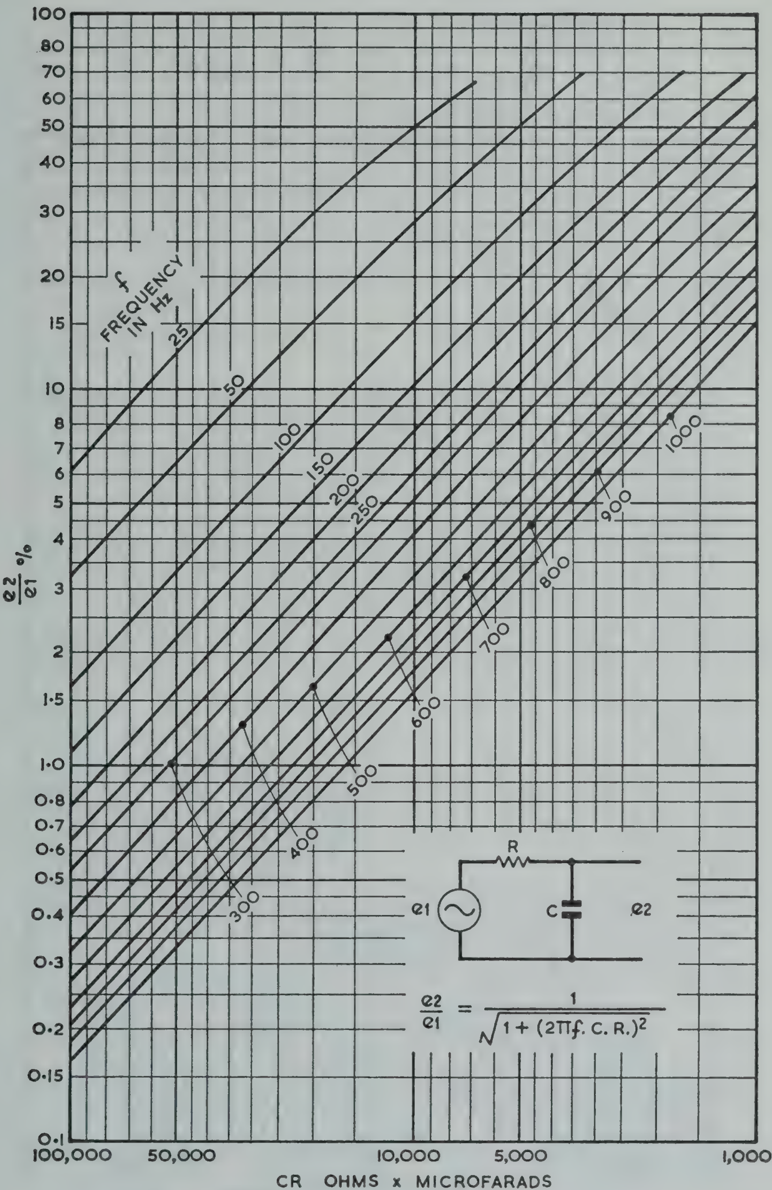
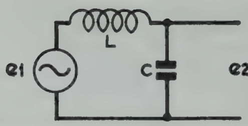


Fig. 67. Ripple attenuation of RC filter sections.



$$\frac{e2}{e1} = \frac{1}{(2\pi f)^2\ LC-1}$$

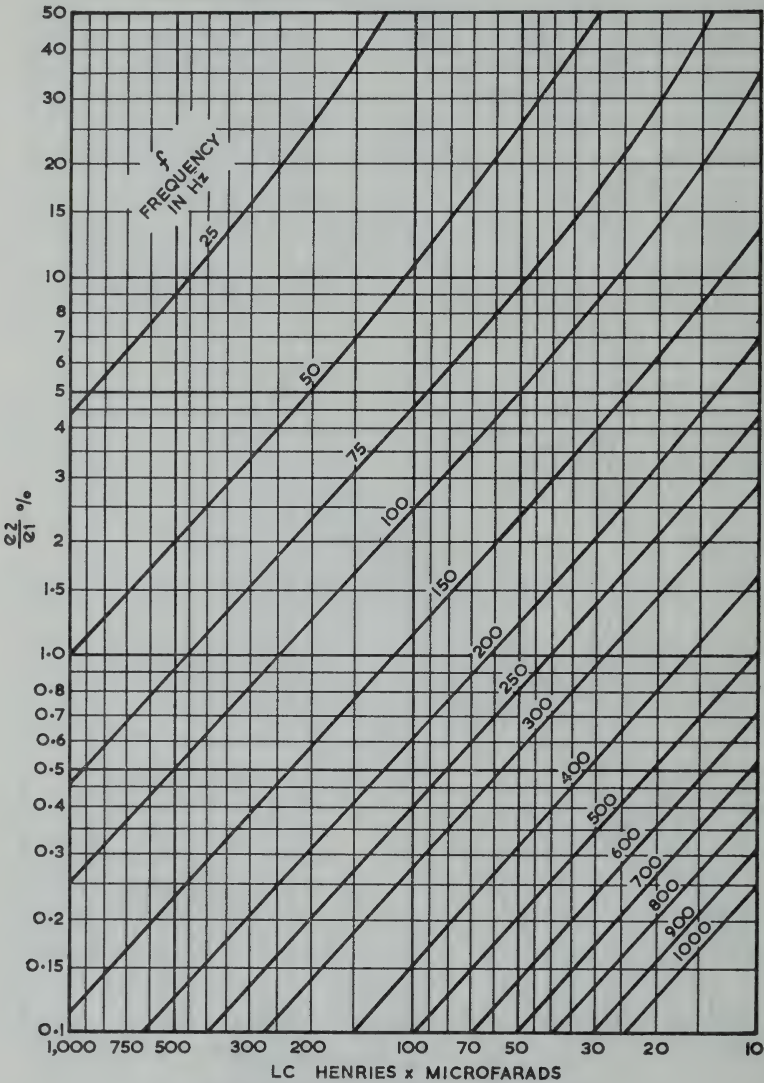


Fig. 68. Ripple attenuation of LC filter sections.

DESIGNATION OF EMISSIONS

Emissions are designated in the Radio Regulations, Geneva, 1968, according to their classification and bandwidth.

SECTION I — CLASSIFICATION

Emissions are classified and symbolized according to the following characteristics:

(*a*) Type of modulation of main carrier.
(*b*) Type of transmission.
(*c*) Supplementary characteristics.

Note: As an exception to the undermentioned, Damped Waves are designated by B.

(*a*) *Types of modulation of main character*	*Symbol*
(i) Amplitude	A
(ii) Frequency (or phase)	F
(iii) Pulse	P

(*b*) *Types of transmission*	
(i) Absence of any modulation intended to carry information	0
(ii) Telegraphy without the use of a modulating audio frequency	1
(iii) Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies, or by the on-off keying of the modulated emission (special case: an unkeyed modulated emission)	2
(iv) Telephony (including sound broadcasting)	3
(v) Facsimile (with modulation of main carrier either directly or by a frequency modulated sub-carrier)	4
(vi) Television (vision only)	5
(vii) Four-frequency diplex telegraphy	6
(viii) Multichannel voice frequency telegraphy	7
(ix) Cases not covered by the above	9

(*c*) *Supplementary characteristics*	*Symbol*
(i) Double sideband	(None)
(ii) Single sideband, reduced carrier	A
Single sideband, full carrier	H
Single sideband, suppressed carrier	J
(iii) Two independent sidebands	B
(iv) Vestigial sideband	C
(v) Pulse—amplitude modulated	D
Pulse—width (or duration) modulated	E
Pulse—phase (or position) modulated	F
Pulse—code modulated	G

PHONETIC ALPHABET

A	Alfa	J	Juliet	S	Sierra
B	Bravo	K	Kilo	T	Tango
C	Charlie	L	Lima	U	Uniform
D	Delta	M	Mike	V	Victor
E	Echo	N	November	W	Whiskey
F	Foxtrot	O	Oscar	X	X-ray
G	Golf	P	Papa	Y	Yankee
H	Hotel	Q	Quebec	Z	Zulu
I	India	R	Romeo		

Amateurs are not restricted to any particular phonetic code. They should, however, be conversant with the above which is now regularized for world-wide use. (ITU Regulations, Geneva, 1968.)

CLASSIFICATION OF TYPICAL EMISSIONS

Type of Modulation	Type of Transmission	Supplementary Characteristics	Symbol
Amplitude Modulation	With no modulation	—	A0
	Telegraphy without the use of a modulating audio frequency (on-off keying)	—	A1
	Telegraphy by the on-off keying of an amplitude modulating audio frequency or audio frequencies or by the on-off keying of the modulated emission (special case: an unkeyed emission amplitude modulated).	—	A2
	Telephony	D.s.b.	A3
		S.s.b., reduced carrier	A3A
		S.s.b., suppressed carrier	A3J
		2-i.s.b.'s	A3B
	Facsimile (with modulation of main carrier either directly or by a frequency modulated sub-carrier)	—	A4
		S.s.b. reduced carrier	A4A
	Television	Vestigial sideband	A5C
	Multichannel voice frequency telegraphy.	S.s.b. reduced carrier	A7A
	Cases not covered by the above, e.g. a combination of telephony and telegraphy	Two independent sidebands	A9B
Frequency or Phase Modulation	Telegraphy by f.s.k. without the use of a modulating audio frequency: one of two frequencies being emitted at any instant.	—	F1
	Telegraphy by the on-off keying of a frequency modulating audio frequency, or by the on-off keying of a frequency modulated emission (special case: an unkeyed emission amplitude modulated.)	—	F2
	Telephony	—	F3
	Facsimile by direct frequency modulation of the carrier	—	F4
	Television	—	F5
	Four-frequency diplex telegraphy	—	F6
	Cases not covered by the above in which the main carrier is frequency modulated	—	F9
Pulse Modulation	A pulsed carrier without any modulation intended to carry information (e.g. radar)	—	P0
	Telegraphy by the on-off keying of a pulsed carrier without the use of a modulating audio frequency	—	P1D
	Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies or by keying of a modulated pulsed carrier (special case: an unkeyed emission amplitude modulated.)	Audio frequency or audio frequencies modulating the amplitude of the pulses	P2D
		Audio frequency or audio frequencies modulating the width or duration of the pulses	P2E
		Audio frequency or audio frequencies modulating the phase (or position) of the pulses	P2F
	Telephony	Amplitude modulated pulses	P3D
		Width (or duration) modulated pulses	P3E
		Phase (or position) modulated pulses	P3F
		Code modulated pulses (after sampling and quantization)	P3G
	Cases not covered by the above in which the main carrier is pulse modulated	—	P9

AMATEUR TRANSMITTER RATINGS

Methods of calculating power input for A1 and A3 transmitters (p.a. anode voltage multiplied by the anode current in amps, gives the input power in watts) are well known, but other systems, particularly single sideband and grounded grid amplifiers, present a somewhat different problem.

Single Sideband Transmitters

The radio frequency output peak envelope power under linear operation from an A3A or A3J transmitter must not exceed that from an A3 transmitter working at an overall efficiency of 66 per cent when supplied with the appropriate maximum permitted d.c. input. The output power shall be measured, using an oscilloscope, by the following process:

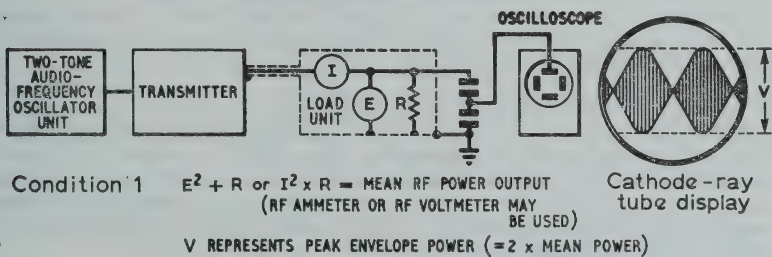
(i) Adjust the A3 transmitter output stage for class C working and apply a pure sinusoidal tone to the transmitter. With the d.c. input power limited to the maximum value appropriate to the frequency band concerned note the peak-to-peak deflection on the cathode-ray oscilloscope.

(ii) Adjust the transmitter for single sideband linear operation and replace the tone by speech; the maximum deflection on the cathode-ray oscilloscope, showing the r.f. output caused by the peaks of speech, should not be greater than twice the previously measured deflection obtained with tone input.

As an alternative, the output power of an s.s.b. transmitter may be measured using a resistive dummy load, r.f. ammeter or voltmeter and oscilloscope, by the following method:

(i) Apply two non-harmonically related sinusoidal tones of equal amplitude to the s.s.b. transmitter, with the carrier fully suppressed, and adjust the input power to give a mean radio frequency output power under linear operation of 200 watts (*see Note 1*) when measured into a resistive load by means of an r.f. meter (*see Note 2*). Under this condition note the peak-to-peak deflection on the cathode-ray oscilloscope (*see Note 3*).

(ii) Replace the tone by speech; the maximum vertical deflection on the cathode-ray oscilloscope shall not be greater than the previously recorded deflection obtained with the two-tone input.



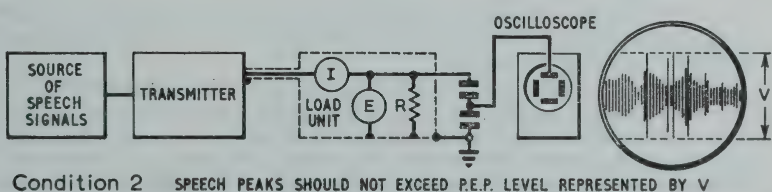


Fig. 69. The set-ups and displays obtained when using the second method of adjusting a single-sideband transmitter.

Note 1. 200 watts mean radio frequency output power in the case of those bands limited to a maximum d.c. input power of 150 watts; 66⅔ and 13⅓ watts for those bands limited to a maximum d.c. input power of 50 watts and 10 watts respectively.
Note 2. In the case of v.h.f. and u.h.f. measurements the r.f. meter may be replaced by a crystal rectifier and calibrated meter; for s.h.f. measurements a bolometer may be used.
Note 3. In the case of v.h.f., u.h.f. and s.h.f. measurements, this use of an oscilloscope may not be practical. In this case the test may be limited to a measurement of the mean radio frequency output power as outlined in part (i) of the procedure.

Output Power of a S.S.B. Transmitter using a Two Tone Test Input

50 ohm dummy load (R)			75 ohm dummy load (R)		
Current (amps)	Mean Power output (watts)	P.E.P. output (watts)	Current (amps)	Mean Power output (watts)	P.E.P. output (watts)
0·5	12·5	25	0·5	19	38
1·0	50·0	100	1·0	75	150
1·5	112·5	225	1·5	168·75	337·5
2·0	200	400	1·63	200	400

Frequency Modulation

The MPT states that: "The carrier frequency [of an f.m. signal] must be at least 10 kHz within the limits of the frequency band in use and that the maximum deviation of carrier frequency shall not exceed 2·5 kHz. The maximum effective modulating frequency shall be limited to 4 kHz, and the audio frequency input to the frequency modulator at any frequency above 4 kHz snall not be less than 26db below the maximum input at lower frequencies."

Although the MPT does not state the maximum effective modulating frequency for other types of phone operation, it is good practice to restrict the bandwidth to 4 kHz or less (a frequency response of 500 to 2500 Hz is generally considered adequate for communication purposes).

Earthed or Grounded Grid Power Amplifiers

In the opinion of the RSGB Technical Committee, the power input, effectively, to a grounded grid power amplifier stage should be reckoned as 10 per cent greater than the product of the anode voltage and anode current to that stage. One proviso is, however, that to prevent unreasonable driving power being used the power input to the driver stage should not exceed 50 per cent of the d.c. power input to the driven stage.

Pulse Modulation

The use of pulse modulation is permitted in the bands 2350-2400, 5700-5800 and 10,050-10,450 MHz, the systems specified being P1D, P2D, P2E, P3D and P3E. These are defined on page 84.

The maximum mean d.c. power input is 25 watts and 2·5 kW peak input power at the crest of the pulse. The limit of 2·5 kW peak d.c. input implies a maximum peak-to-mean ratio of 100 : 1, or a 1 per cent duty ratio.

The duty ratio is defined as the ratio between pulse duration and pulse repetition period. For example, if the pulse duration is t and the interval between the beginning of one pulse and the beginning of the next is T, then t/T is the duty ratio.

It is essential for a station employing pulse modulation to have a suitable cathode-ray oscilloscope in order to set up the transmitter. To display the envelope of the r.f. pulse, some of the r.f. output should be applied to the Y plates of the tube, the X plates being operated from the time base which should be locked at a sub-multiple of the repetition frequency.

REGION 1 HF BAND PLAN

This plan is supported by all IARU societies in Europe and Africa.

Frequency band	Types of emission
3·5 — 3·6MHz 3·6 — 3·8MHz	CW only CW and phone
7·0 — 7·04MHz 7·04 — 7·1MHz	CW only CW and phone
14·0 — 14·1MHz Around 14·090MHz 14·1 — 14·35MHz	CW only RTTY CW and phone
21·0 — 21·15MHz 21·15 — 21·45MHz	CW only CW and phone
28·0 — 28·2MHz 28·2 — 29·7MHz	CW only CW and phone

Note: 3,500–3,510kHz and 3,790–3,800kHz are reserved for intercontinental working.

REGION 1 VHF-UHF BAND PLAN

4m band

70·025–70·1MHz	CW only.
70·1–70·675MHz	All modes, including ssb.
70·675–70·7MHz	Beacons.
70·26MHz	National mobile net calling.
70·56MHz	RTTY.

2m band

144·00–144·15MHz	CW only.
144·15–144·5MHz	Zone A, the South West, (*Berks, Cornwall, Devon, Dorset, Hants, Somerset, Wilts, Channel Is., Brecon, Cardigan, Carmarthen, Glamorgan, Gloucester, Hereford, Monmouth, Pembroke, Radnor, Worcester.*
144·5–145·1MHz	Zone B, the South East. (*Kent, Surrey, Sussex, Beds, Bucks, Essex, Herts, London, Middlesex.*)
145·1–145·5MHz	Zone C, the Midlands. (*Cambs, Hunts, Leicester, Norfolk, Northants, Oxford, Rutland, Suffolk, Warwickshire, Anglesey, Caernarvon, Cheshire, Denbigh, Flints, Merioneth, Montgomery, Shropshire, Stafford*).
145·5–145·95MHz	Zone D, the North, Scotland and Northern Ireland. (*Derby, Lancs, Lincs, Notts, Yorks, all Scottish and Northern Ireland counties, Isle of Man, Cumberland, Durham, Northumberland, Westmorland.*)
145·95–146·00MHz	Beacons.

70cm band

432·0–432·1MHz	CW only.
432·1–432·2MHz	Zone 1. (*Berks, Cornwall, Devon, Dorset, Hants, Somerset, Wilts, Channel Is.*)
432·2–432·3MHz	Zone 2. (*Brecon, Cardigan, Carmarthen, Glamorgan, Gloucester, Hereford, Monmouth, Pembroke, Radnor, Worcester.*)
432·3–432·5MHz	Zone 3. (*Kent, Surrey, Sussex.*)
432·5–432·7MHz	Zone 4. (*Beds, Bucks, Essex, Herts, London, Middlesex.*)
432·7–432·9MHz	Zone 5. (*Cambs, Hunts, Leicester, Norfolk, Northants, Oxford, Rutland, Suffolk, Warwickshire.*)
432·9–433·1MHz	Zone 6. (*Anglesey, Caernarvon, Cheshire, Denbigh, Flints, Merioneth, Montgomery, Shropshire, Stafford.*)
433·1–433·3MHz	Zone 7. (*Derby, Lancs, Lincs, Notts, Yorks.*)
433·3–433·45MHz	Zone 8. (*all Scotland, Northern Ireland, Isle of Man, Cumberland, Durham, Northumberland, Westmorland.*)
433·45–433·5MHz	Beacons.
433·5–434MHz	Television sound.
434 to top of band	Video.

23cm band (narrow band communication segment)

1,296–1,296·15MHz	CW only.
1,296·15–1,297·95MHz	All modes (narrow band).
1,297·95–1,298MHz	Beacons.

Special services

2m band

144·09–144·10MHz	CW for random meteor scatter contacts, but not held exclusively for this.
144·1–144·15MHz	SSB *only* when artificial satellites or translators are operational.
145·85–145·95MHz	SSB *only* when artificial satellites or translators are operational.
145·0MHz	Mobile calling channel (international).
145·3MHz	RTTY international and UK north.
144·6MHz	RTTY UK south.
145·41MHz	SSB calling channel (international).

70cm band

433·3MHz	RTTY international and UK north.
432·6MHz	RTTY UK south.
432·1MHz	SSB calling channel (international).
425–429MHz	Self excited transmissions.

COASTAL RADIO SERVICES

The following frequencies are used by British coastal radio stations:

1827 kHz	Wick and Valentia	1883 kHz	Port Patrick
1834 kHz	Niton	2670 kHz	Ilfracombe
1841 kHz	Lands End	2719 kHz	Cullercoats
1848 kHz	North Foreland	2740 kHz	Oban
1856 kHz	Stonehaven	3617 kHz	Wick
1869 kHz	Humber	3778 kHz	Humber

AMATEUR BANDS IN THE UK

Amateur (Sound) and (Sound Mobile) Licences

Note No.	Frequency bands (MHz)	Classes of emission	Power	
			Maximum dc input power	RF output pep for A3A and A3J emissions only
1 and 5	1·8–2		10W	$26\frac{2}{3}$W
2	3·5–3·8			
	7–7·10 14–14·35 21–21·45 28–29·7		150W	400W
1 and 3	70·025–70·7	A1, A2, A3	50W	$133\frac{1}{3}$W
1 and 4	144–145 145–146	A3A, A3H A3J, F1, F2 and F3		
 1 1 1 1 1 1	425– 429 432– 450 1,215– 1,325 2,300– 2,450 3,400– 3,475 5,650– 5,850 10,000–10,500		150W	400W
	21,000–22,000			
1 and 6 1 and 6 1 and 6	2,350– 2,400 5,700– 5,800 10,050–10,450	P1D, P2D P2E, P3D and P3E	25W mean power and 2·5kW peak power	—
	21,150–21,850			

Notes

1. This band is allocated to stations in the amateur service on a secondary basis on condition that they shall not cause interference to other services.
2. This band is shared by other services.
3. This band is available to amateurs *until further notice* provided that use by the licensee of *any* frequency in the band shall cease immediately on the demand of a Government official.
4. The following spot aeronautical frequencies must be avoided *whenever* this band is used: 144·0, 144·09, 144·18, 144·27, 144·36, 144·45, 144·54, 144·63, 144·72, 144·81 and 144·9MHz.
5. This type of transmission known as radio teleprinter (rtty) may not be used in this band.
6. Use by the licensee of *any* frequency in this band shall be only with the prior written consent of the Minister of Posts and Telecommunications.

Amateur television

An additional licence is required for the use of amateur television. Operation is permitted in the following bands: 425–429*, 432-445*, 1,225–1,290*, 2,300–2,450*, 5,650–5,850*, 10,000–10,500*, and 21,000–22,000MHz.

* Subject to Note 1 above.

STANDARD FREQUENCY SERVICES

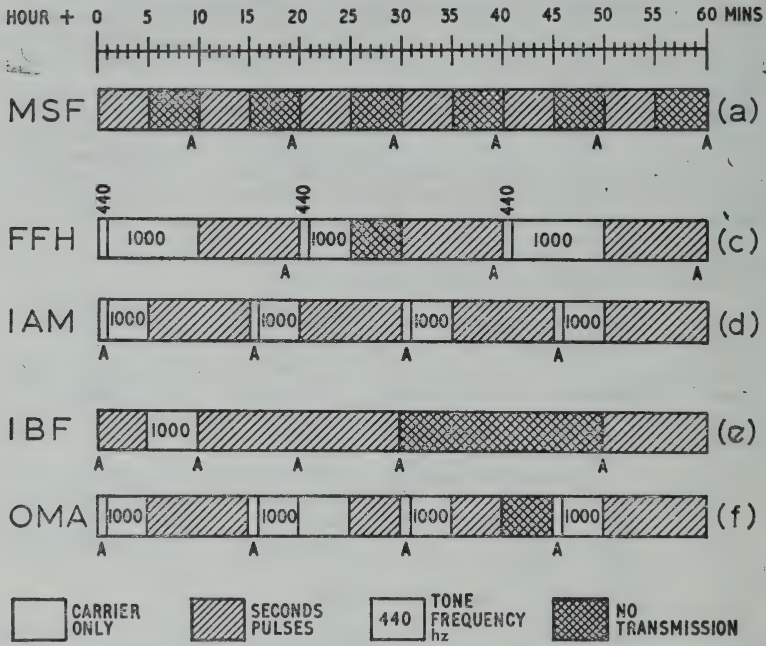


Fig. 70. Modulation schedules of standard frequency stations. FFH (Paris) transmits on 2·5 MHz from 08.00-16.30 UT on Tuesdays and Fridays, IAM (Rome) on 5 MHz from 07.30-08.30 UT. IBF (Turin) on 5 MHz daily from H+15 to H. MSF (Rugby) on 2·5, 5 and 10 MHz and OMA (Prague) on 2·5 MHz are in continuous operation. The transmissions from MSF are suppressed in alternate 5 min. periods to permit time-sharing with other standard frequency stations in Europe. The letters A indicate the times of voice or morse announcements.

MSF Transmissions

Station	MSF 60kHz	MSF 2·5, 5 & 10MHz
Location	52° 22′ N, 1° 11′ W	
Carrier power to aerial (kW)	20	0·25
Daily period of operation (hours)	24 (*a*)	12 (*b*)
Duration of time signal emission (minutes)	continuous	5 in (*b*) each 10
Accuracy of frequency (parts in 10^{10})	± 1 (*c*) relative to atomic scale	
Accuracy of time signals (ms)	± 1 relative to UTC	

Notes: (*a*) There is an interruption for maintenance from 1000 to 1400 gmt (1000 to 1400 bst, when applicable) on the first Tuesday of each month.
(*b*) The hf emissions are interrupted in alternate 5 minute periods.
(*c*) These are statutory limits: the departures from nominal frequency will not usually exceed a few parts in 10^{11}.

WWV AND WWVH TRANSMISSIONS

WWV transmits from Fort Collins, Colorado, USA, (40° 40′ 49″ N 105° 02′ 27″ W) on 2·5, 5, 10, 15, 20 and 25MHz.

WWVH transmits from Kauai, Hawaii, USA, (21° 59′ 31″ N 159° 46′ 04″ W) on 2·5, 5, 10, 15 and 20MHz.

Details of transmissions

Voice announcements of time of day (UT) will be given once a minute. The WWV announcements will be made by a male voice and the WWVH announcements by a female voice.

The *audio tones*, 440, 500 and 600Hz will be of 45s duration. See format wheel for the times of the tones.

There will be **no morse code** anywhere in the format. UT2 corrections, GEO-ALERTS and other announcements will be in plain language.

There will be **no double tick** on the minute. This double tick will be replaced by a seconds pulse lengthened to 0·8s duration. Also, there will be no 29th or 59th second pulse. The zero (60th) second pulse of 0·8s duration is changed from 0·8s of 1,000Hz on WWV and 0·8s of 1,200Hz on WWVH to 0·8s of 1,500Hz on the zero second of the first minute of the hour.

The standard **IRIG-H time code** will be broadcast continuously. This is a 1pps code of 1min time frame carried on a 100Hz audio subcarrier.

There will be **no silent period** on either station. A quasi-silent period will be in effect at the times shown on the format wheel. During these periods only seconds pulses, voice time announcements, and the 100Hz code will be broadcast.

The 440Hz 1 hour mark is deleted during the first hour of the UT day.

(See page 92 for format).

NAVIGATION AND GALE WARNINGS BROADCAST BY COASTAL RADIO STATIONS

(See page 88)

Navigational Warnings

04.03, 08.03, 16.03 and 20.03 GMT broadcast by Wick, North Foreland, Lands End and Malin.

04.33, 08.33, 16.33 and 20.33 GMT broadcast by Humber, Niton, Port Patrick and Valentia.

Gale Warnings

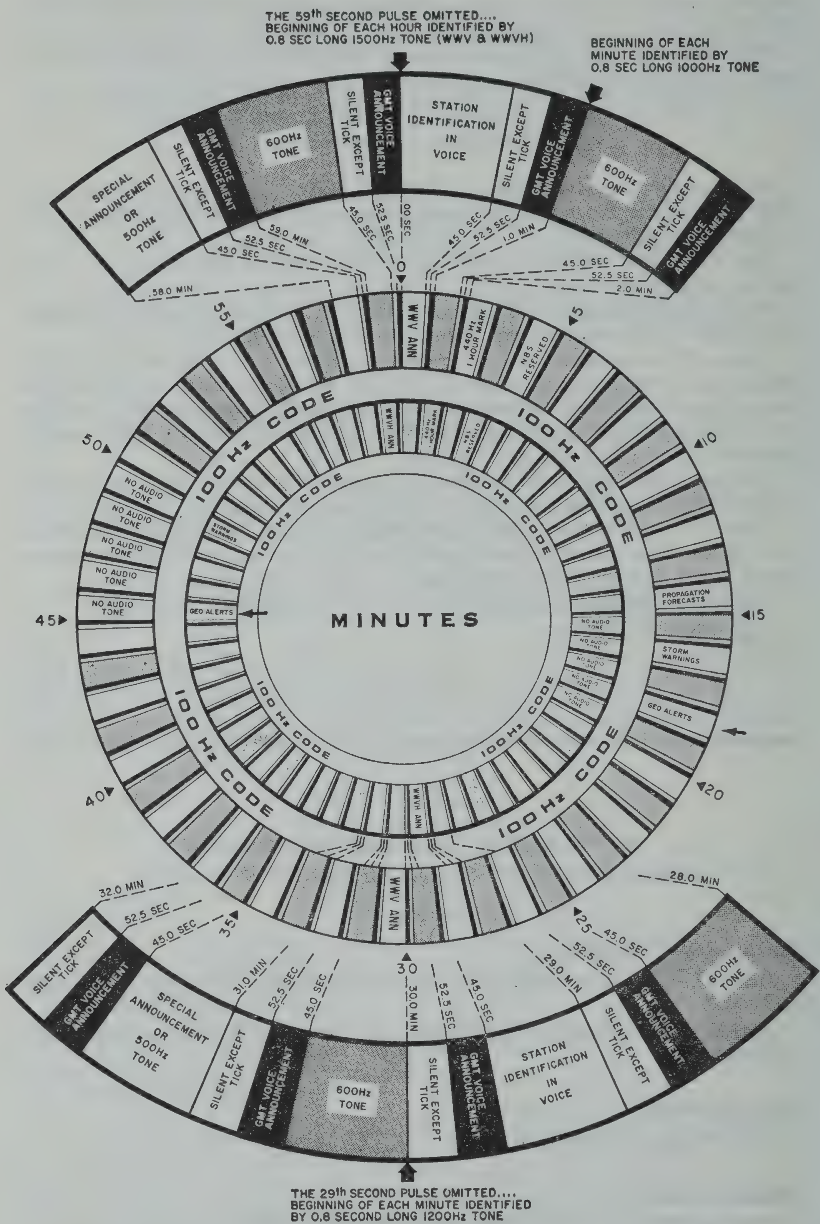
03.03, 09.03, 15.03 and 21.03 GMT.

Weather Bulletins

08.03 and 20.03 GMT by Cullercoats, Lands End, North Foreland, Oban and Wick.

08.33 and 20.33 GMT by Humber, Ilfracombe, Niton, Port Patrick, Stonehaven and Valentia.

WWV Broadcast format (typical)



WWVH Broadcast format (typical)

Fig. 71.

RADIO FREQUENCY SPECTRUM

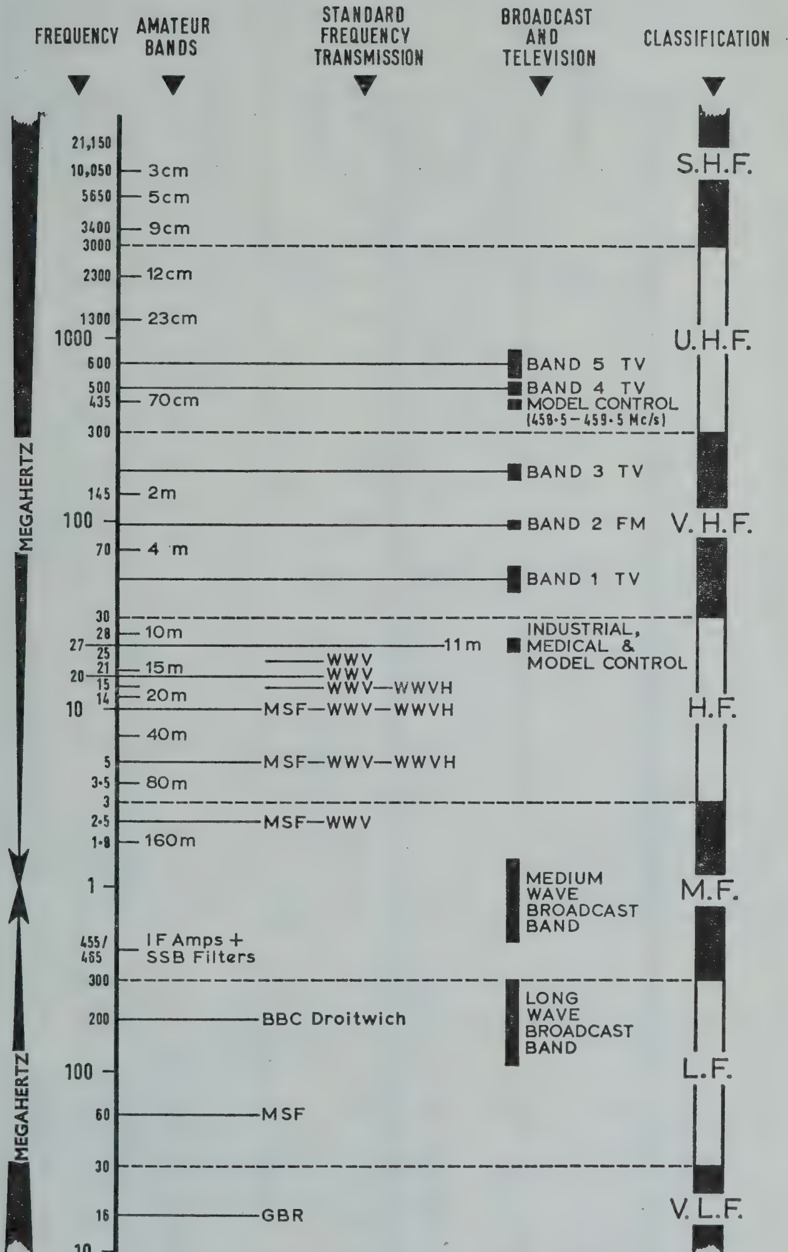


Fig. 72.

FREQUENCY V. WAVELENGTH

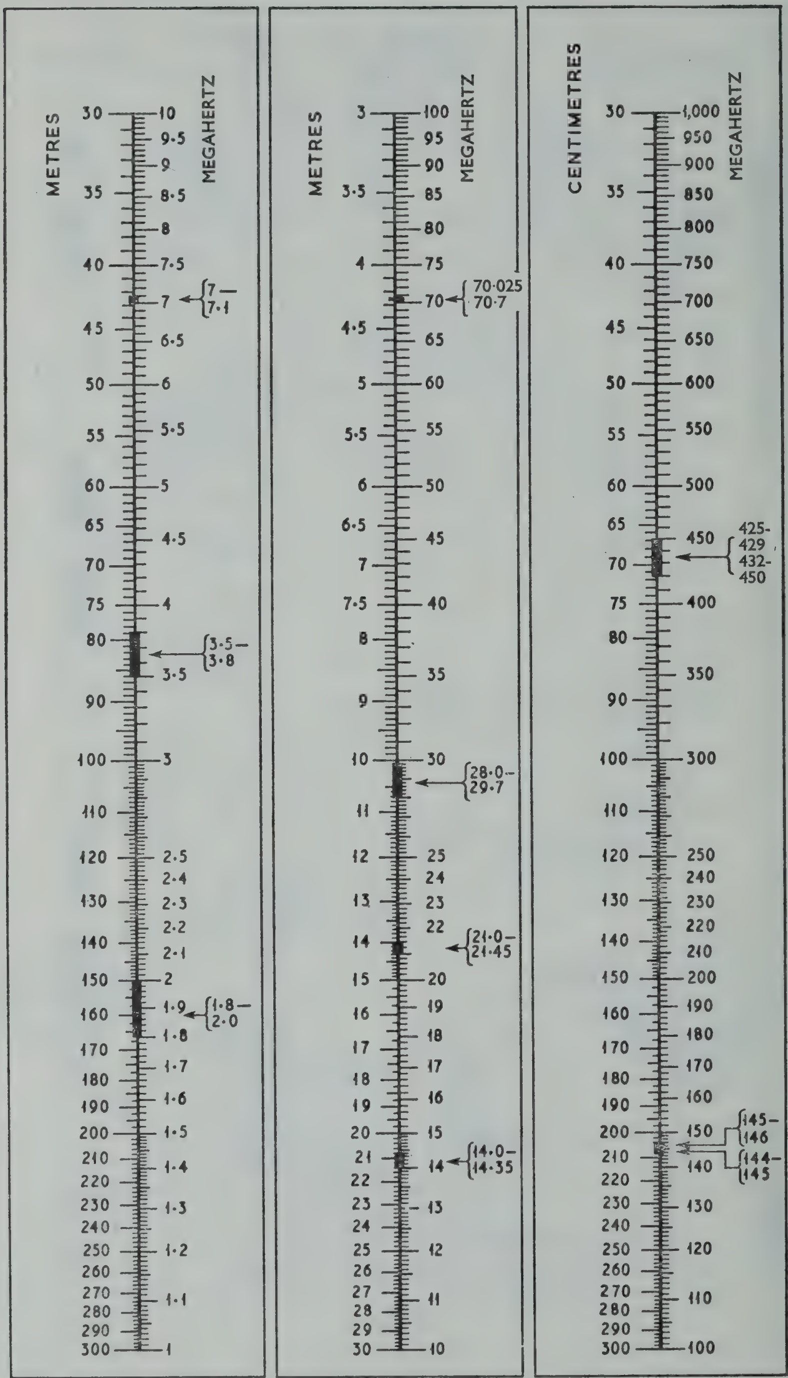


Fig. 73.

RADIO AND TV SERVICES

UK LONG AND MEDIUM WAVE BROADCAST FREQUENCIES

Frequency	Programme
200 kHz	BBC Radio 2
647 kHz	BBC Radio 3
692 kHz	BBC Radio 4 North
809 kHz	BBC Radio 4 Scottish
881 kHz	BBC Radio 4 Welsh
908 kHz	BBC Radio 4 London
1052 kHz	BBC Radio 4 West
1088 kHz	BBC Radio 4 Midlands
1151 kHz	BBC Radio 4 Northern Ireland
1214 kHz	BBC Radio 1
1295 kHz	Manx Radio *
1457 kHz	BBC Radio 4 West
1546 kHz	BBC Radio 3
1594 kHz	Manx Radio *

* Commercial. Also broadcasts on 89 MHz in Band 2.

WORLD TELEVISION SYSTEMS

System	Lines	Channel Band-width	Vision Band-width	Sound Vision Separation	Vestigial Sideband	Modulation Vision	Modulation Sound
A	405	5 MHz	3 MHz	−3·5 MHz	0·75 MHz	Positive	A.m.
B	625	7 MHz	5 MHz	+5·5 MHz	0·75 MHz	Negative	F.m.
C	625	7 MHz	5 MHz	+5·5 MHz	0·75 MHz	Positive	A.m.
D	625	8 MHz	6 MHz	+6·5 MHz	0·75 MHz	Negative	F.m.
E	819	14 MHz	10 MHz	±11·15 MHz	2 MHz	Positive	A.m.
F	819	7 MHz	5 MHz	+5·5 MHz	0·75 MHz	Positive	A.m.
G	625	8 MHz	5 MHz	+5·5 MHz	0·75 MHz	Negative	F.m.
H	625	8 MHz	5 MHz	+5·5 MHz	1·25 MHz	Negative	F.m.
I	625	8 MHz	5·5 MHz	+6 MHz	1·25 MHz	Negative	F.m.
K	625	8 MHz	6 MHz	+6·5 MHz	0·75 MHz	Negative	F.m.
K′	625	4 MHz	6 MHz	+6·5 MHz	1·25 MHz	Negative	F.m.
L	625	8 MHz	6 MHz	+6·5 MHz	1·25 MHz	Positive	A.m.
M	525	6 MHz	4·2 MHz	+4·5 MHz	0·75 MHz	Negative	F.m.
N	625	6 MHz	4·2 MHz	+4·5 MHz	0·75 MHz	Negative	F.m.

System	Countries
A	United Kingdom, Republic of Ireland.
B	Austria, Australia, West Germany, Italy, Holland, Morocco, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Syria, United Arab Republic, Yugoslavia.
C	Belgium.
D	Czechoslovakia, East Germany, Poland, USSR.
E	France, Monaco.
F	Luxembourg.
G	Austria, West Germany, Italy, Holland.
H	
I	United Kingdom, Republic of Ireland.
J	
K	
L	France.
M	Canada, Japan, United States of America.

AUSTRALIAN TELEVISION CHANNEL FREQUENCIES

Channel	Frequencies	Channel	Frequencies
0	46·25— 51·75 MHz	6	175·25—180·75 MHz
1	57·25— 62·75 MHz	7	182·25—187·75 MHz
2	64·25— 69·75 MHz	8	189·25—194·75 MHz
3	86·25— 91·75 MHz	9	196·25—201·75 MHz
4	95·25—100·75 MHz	10	209·25—214·75 MHz
5	102·25—107·75 MHz	11	216·25—221·75 MHz
5A	138·25—143·75 MHz		

All transmissions on 625 lines (System B).

NEW ZEALAND TELEVISION CHANNEL FREQUENCIES

Channel	Frequencies	Channel	Frequencies
1	45·25— 50·75 MHz	6	189·25—194·75 MHz
2	55·25— 60·75 MHz	7	196·25—201·75 MHz
3	62·25— 67·75 MHz	8	203·25—208·75 MHz
4	175·25—180·75 MHz	9	210·25—215·75 MHz
5	182·25—187·75 MHz		

All transmissions on 625 lines (System B).

REPUBLIC OF IRELAND TELEVISION CHANNEL FREQUENCIES

Channel	Frequencies	Channel	Frequencies
7 *	181·25—184·75 MHz	IE	183·25—189·25 MHz
11 *	201·25—204·75 MHz	IF†	191·25—197·25 MHz
IA†	45·75—51·75 MHz	IG†	199·25—205·25 MHz
IB†	53·75—59·75 MHz	IH†	207·25—213·25 MHz
IC†	61·75—67·75 MHz	IJ†	215·25—221·25 MHz
ID†	175·25—181·25 MHz		

* 425 lines system (System A). † 625 lines system (System I).

USA TELEVISION CHANNEL FREQUENCIES

V.H.F.

Channel	Frequencies	Channel	Frequencies
2	55·25— 59·75 MHz	8	181·25—185·75 MHz
3	61·25— 65·75 MHz	9	187·25—191·75 MHz
4	67·25— 71·75 MHz	10	193·25—197·75 MHz
5	77·25— 81·75 MHz	11	199·25—203·75 MHz
6	83·25— 87·75 MHz	12	205·25—209·75 MHz
7	175·25—179·75 MHz	13	211·25—215·75 MHz

USA TV CHANNEL FREQUENCIES—*continued*

U.H.F.

Channel	Frequencies	Channel	Frequencies
14	471·25—475·75 MHz	49	681·25—685·75 MHz
15	477·25—481·75 MHz	50	687·25—691·75 MHz
16	483·25—487·75 MHz	51	693·25—697·75 MHz
17	489·25—493·75 MHz	52	699·25—703·75 MHz
18	495·25—499·75 MHz	53	705·25—709·75 MHz
19	501·25—505·75 MHz	54	711·25—715·75 MHz
20	507·25—511·75 MHz	55	717·25—721·75 MHz
21	513·25—517·75 MHz	56	723·25—727·75 MHz
22	519·25—523·75 MHz	57	729·25—733·75 MHz
23	525·25—529·75 MHz	58	735·25—739·75 MHz
24	531·25—535·75 MHz	59	741·25—745·75 MHz
25	537·25—541·75 MHz	60	747·25—751·75 MHz
26	543·25—547·75 MHz	61	753·25—757·75 MHz
27	549·25—553·75 MHz	62	759·25—763·75 MHz
28	555·25—559·75 MHz	63	765·25—769·75 MHz
29	561·25—565·75 MHz	64	771·25—775·75 MHz
30	567·25—571·75 MHz	65	777·25—781·75 MHz
31	573·25—577·75 MHz	66	783·25—787·75 MHz
32	579·25—583·75 MHz	67	789·25—793·75 MHz
33	585·25—589·75 MHz	68	795·25—799·75 MHz
34	591·25—595·75 MHz	69	801·25—805·75 MHz
35	597·25—601·75 MHz	70	807·25—811·75 MHz
36	603·25—607·75 MHz	71	813·25—817·75 MHz
37	609·25—613·75 MHz	72	819·25—823·75 MHz
38	615·25—619·75 MHz	73	825·25—829·75 MHz
39	621·25—625·75 MHz	74	831·25—835·75 MHz
40	627·25—631·75 MHz	75	837·25—841·75 MHz
41	633·25—637·75 MHz	76	843·25—847·75 MHz
42	639·25—643·75 MHz	77	849·25—853·75 MHz
43	645·25—649·75 MHz	78	855·25—859·75 MHz
44	651·25—655·75 MHz	79	861·25—865·75 MHz
45	657·25—661·75 MHz	80	867·25—871·75 MHz
46	663·25—667·75 MHz	81	873·25—877·75 MHz
47	669·25—673·75 MHz	82	879·25—883·75 MHz
48	675·25—679·75 MHz	83	885·25—889·75 MHz

All transmissions on 525 lines (System M).

BAND I—CHANNEL FREQUENCIES

Channel	Frequencies	
	Sound	Vision
1	41·50 MHz	45·00 MHz
2	48·25 MHz	51·75 MHz
3	53·25 MHz	56.75 MHz
4	58·25 MHz	61·75 MHz
5	63·25 MHz	66·75 MHz

All transmissions on 405 line system (System A).

BAND III—CHANNEL FREQUENCIES

Channel	Frequencies	
	Sound	Vision
6	176·25 MHz	179·75 MHz
7	181·25 MHz	184·75 MHz
8	186·25 MHz	189·75 MHz
9	191·25 MHz	194·75 MHz
10	196·25 MHz	199·75 MHz
11	201·25 MHz	204·75 MHz
12	206·25 MHz	209·75 MHz
13	211·25 MHz	214·75 MHz

All transmissions on 405 line system (System A).

BAND IV—CHANNEL FREQUENCIES

Channel	Frequency (MHz) Vision		Sound	Channel	Frequency (MHz) Vision		Sound
21	471·25	—	477·25	28	527·25	—	533·25
22	479·25	—	485·25	29	535·25	—	541·25
23	487·25	—	493·25	30	543·25	—	549·25
24	495·25	—	501·25	31	551·25	—	557·25
25	503·25	—	509·25	32	559·25	—	565·25
26	511·25	—	517·25	33	567·25	—	573·25
27	519·25	—	525·25	34	575·25	—	581·25

All transmissions on 625 line system (System I).

BAND V—CHANNEL FREQUENCIES

Channel	Frequency (MHz) Vision		Sound	Channel	Frequency (MHz) Vision		Sound
39	615·25	—	621·15	54	735·35	—	741·25
40	623·25	—	629·25	55	743·25	—	749·25
41	631·25	—	637·25	56	751·25	—	757·25
42	639·25	—	645·25	57	759·25	—	765·25
43	647·25	—	653·25	58	767·25	—	773·25
44	655·25	—	661·25	59	775·25	—	781·25
45	663·25	—	669·25	60	783·25	—	789·25
46	671·25	—	677·25	61	791·25	—	797·25
47	679·25	—	685·25	62	799·25	—	805·25
48	687·25	—	693·25	63	807·25	—	813·25
49	695·25	—	701·25	64	815·25	—	821·25
50	703·25	—	709·25	65	823·25	—	829·25
51	711·25	—	717·25	66	831·25	—	837·25
52	719·25	—	725·25	67	839·25	—	845·25
53	727·25	—	733·25	68	847·25	—	853·25

All transmissions on 625 line system (System I).

UK BAND 1 STATIONS

Station	Channel	Aerial Polarization	Maximum Vision E.R.P.
Abergavenny (BBC Wales)	3	Horizontal	30 W *
Aldeburgh	5	Vertical	25 W *
Ashkirk	1	Vertical	18 kW *
Ayr	2	Horizontal	50 W *
Ballachulish	2	Vertical	100 W *
Ballater	1	Vertical	10 W *
Ballycastle	4	Horizontal	50 W *
Barnstaple	3	Horizontal	200 W *
Betws-y-Coed (BBC Wales)	4	Horizontal	35 W *
Bexhill	3	Horizontal	150 W *
Blaen-Plwyf (BBC Wales)	3	Horizontal	3 kW *
Bodmin	5	Horizontal	10 W *
Bressay	3	Vertical	6 kW *
Brighton	2	Vertical	400 W *
Brougher Mountain	5	Vertical	7 kW *
Bude	4	Vertical	100 W *
Cambridge	2	Horizontal	100 W *
Campbeltown	5	Vertical	500 W *
Canterbury	5	Vertical	30 W *
Cardigan (BBC Wales)	2	Horizontal	45 W *
Carmarthen (BBC Wales)	1	Vertical	20 W *
Churchdown Hill	1	Horizontal	250 W *
Crystal Palace	1	Vertical	200 kW
Divis	1	Horizontal	12 kW
Dolgellau (BBC Wales)	5	Vertical	25 W *
Douglas	5	Vertical	3 kW *
Dundee Law	2	Vertical	10 W *
Eastbourne	5	Vertical	50 W *
Ffestiniog (BBC Wales)	5	Horizontal	50 W *
Folkestone	4	Horizontal	40 W *
Forfar	5	Vertical	5 kW *
Fort William	5	Horizontal	1·5 kW
Girvan	4	Vertical	20 W *
Grantown	1	Horizontal	400 W *
Hastings	4	Horizontal	15 W *
Haverfordwest (BBC Wales)	4	Horizontal	10 kW *
Hereford	2	Horizontal	50 W *
Holme Moss	2	Vertical	100 kW *
Holyhead (BBC Wales)	4	Horizontal	10 W *
Hungerford	4	Horizontal	25 W *
Isles of Scilly	3	Horizontal	20 W *
Kendal	1	Horizontal	25 W *
Kilkeel	3	Horizontal	25 W *
Kilvey Hill (BBC Wales)	2	Horizontal	500 W *
Kingussie	5	Horizontal	35 W *
Kinlochleven	1	Vertical	5 W *
Kirk O'Shotts	3	Vertical	100 kW
Larne	3	Horizontal	50 W *
Les Platons	4	Horizontal	1 kW
Llanddona (BBC Wales)	1	Vertical	6 kW *
Llandrindod Wells (BBC Wales)	1	Horizontal	1·5 kW
Llanelli (BBC Wales)	3	Vertical	15 W *
Llangollen (BBC Wales)	1	Horizontal	35 W *
Lochgilphead	1	Vertical	20 W *
Londonderry	2	Horizontal	1·5 kW *
Machynlleth (BBC Wales)	5	Horizontal	50 W *

UK BAND 1 STATIONS—*continued*

Station	Channel	Aerial Polarization	Maximum Vision E.R.P.
Maddybenny More	5	Horizontal	20 W *
Manningtree	4	Horizontal	5 kW *
Meldrum	4	Horizontal	17 kW *
Melvaig	4	Vertical	25 kW *
Millburn Muir	1	Vertical	10 W *
Morecambe Bay	3	Horizontal	5 kW *
Newry	4	Vertical	30 W *
Northampton	3	Vertical	90 W *
North Hessary Tor	2	Vertical	15 kW *
Oban	4	Vertical	3 kW *
Okehampton	4	Vertical	40 W *
Orkney	5	Vertical	15 kW *
Oxford	2	Horizontal	650 W *
Penifiler	1	Horizontal	25 W *
Perth	4	Vertical	25 W *
Peterborough	5	Horizontal	1 kW *
Pitlochry	1	Horizontal	200 W *
Pontop Pike	5	Horizontal	17 kW *
Port Ellen	2	Vertical	50 W *
Redruth	1	Horizontal	10 kW *
Richmond (Yorkshire)	3	Vertical	45 W *
Rosemarkie	2	Horizontal	20 kW *
Rosneath	2	Vertical	20 W *
Rowridge	3	Vertical	100 kW *
Rye	3	Horizontal	50 W *
Sandale	4	Horizontal	30 kW *
Scarborough	1	Horizontal	500 W *
Sheffield	1	Horizontal	50 W
Sidmouth	4	Horizontal	30 W *
Skegness	1	Horizontal	60 W
Skriaig	3	Horizontal	12 kW *
Sutton Coldfield	4	Vertical	100 kW
Swindon	3	Horizontal	200 W *
Swingate	2	Vertical	1·5 kW *
Tacolneston	3	Horizontal	45 kW *
Thrumster	1	Vertical	7 kW *
Toward	5	Vertical	250 W *
Ventnor	5	Horizontal	10 W *
Weardale	1	Horizontal	150 W *
Wensleydale	1	Vertical	20 W *
Wenvoe (BBC 1)	5	Vertical	100 kW
Weymouth	1	Horizontal	50 W *
Whitby	4	Vertical	40 W *

* Directional aerial.

UK V.H.F. (F.M.) STATIONS
BAND II

Station	Frequencies (MHz) Radio 4	Radio 2	Radio 3	Maximum E.R.P. (Each Prog.)
Ashkirk	93·5	89·1	91·3	18 kW *
Ballachulish	92·5	88·1	90·3	15 W
Ballycastle	93·4	89·0	91·2	40 W *
Barnstaple	92·9	88·5	90·7	150 W *
Bath	93·2	88·8	91·0	35 W *
Belmont	93·1	88·8	90·9	8 kW *
Betws-y-Coed	92·6	88·2	90·4	10 W
Blaen-Plwyf	93·1	88·7	90·9	60 kW
Brecon	93·3	88·9	91·1	10 W *
Bressay	92·7	88·3	90·5	10 kW *
Brighton	94·5	90·1	92·3—S	150 W *
Brougher Mountain	93·3	88·9	91·1	2·5 kW
Campbeltown	92·6	88·2	90·4	35 W
Cambridge	93·3	88·9	91·1	20 W *
Carmarthen	92·2	88·5	90·7	10 W *
Churchdown Hill	93·4	89·0	91·2	25 W *
Divis	94·5	90·1	92·3	60 kW
Dolgellau	94·5	90·1	92·3	15 W
Douglas	92·8	88·4	90·6	6 kW *
Ffestiniog	92·5	88·1	90·3	50 W
Forfar	92·7	88·3	90·5	10 kW *
Fort William	93·7	89·3	91·5	1·5 kW
Grantown	94·2	89·8	92·0	350 W
Haverfordwest	93·7	89·3	91·5	10 kW *
Hereford	94·1	89·7	91·9	25 W *
Holme Moss	93·7	89·3	91·5—S	120 kW
Isles of Scilly	93·2	88·8	91·0	20 W
Kendal	93·1	88·7	90·9—S	25 W *
Kilkeel	93·2	88·8	91·0	25 W *
Kingussie	93·5	89·1	91·3	35 W *
Kinlochleven	94·1	89·7	91·9	2 W
Kirk O'Shotts	94·3	89·9	92·1	120 kW
Larne	93·5	89·1	91·3	15 W *
Les Platons	97·1	91·1	94·75	1·5 kW *
Llanddona	94·0	89·6	91·8	12 kW *
Llandrindod Wells	93·5	89·1	91·3	1·5 kW
Llangollen	93·25	88·85	91·05	10 kW *
Llanidloes	92·5	88·1	90·3	5 W
Lochgilphead	92·7	88·3	90·5	10 W *
Londonderry	92·7	88·3	90·55	13 kW *
Machynlleth	93·8	89·4	91·6	60 W *
Maddybenny More	93·1	88·7	90·9	30 W
Manx Radio†	89·0			—
Meldrum	93·1	88·7	90·9	60 kW
Melvaig	93·5	89·1	91·3	22 kW *
Morecambe Bay	94·4	90·0	92·2—S	4 kW *
Newry	93·0	88·6	90·8	30 W *
Northampton	93·3	88·9	91·1—S	60 W *
North Hessary Tor	92·5	88·1	90·3	60 kW
Oban	93·3	88·9	91·1	1·5 kW
Okehampton	93·1	88·7	90·9	15 W *
Orkney	93·7	89·3	91·5	20 kW *
Oxford	93·9	89·5	91·7—S	22 kW *
Penifiler	93·9	89·5	91·7	6 W *
Perth	93·7	89·3	91·5	15 W *

BAND II—*continued*

Station	Frequencies (MHz) Radio 4	Radio 2	Radio 3	Maximum E.R.P. (Each Prog.)
Peterborough	94·5	90·1	92·3	20 kW *
Pitlochry	93·6	89·2	91·4	200 W *
Pontop Pike	92·9	88·5	90·7	60 kW *
Redruth	94·1	89·7	91·9	9 kW *
Rosemarkie	94·0	89·6	91·8	12 kW *
Rowridge	92·9	88·5	90·7	60 kW
Sandale	92·5	88·1	90·3	120 kW
Swaledale	94·0	89·6	91·8	35 W
Scarborough	94·3	89·9	92·1—S	25 W *
Sheffield	94·3	89·9	92·1—S	60 W
Skriaig	92·9	88·5	90·7	10 kW *
Sutton Coldfield	92·7	88·3	90·5—S	120 kW
Swingate	94·4	90·0	92·4—S	7 kW *
Tacolneston	94·1	89·7	91·9	120 kW
Thrumster	94·5	90·1	92·3	10 kW *
Toward	92·9	88·5	90·7	250 W *
Ventnor	93·8	89·4	91·6	20 W
Weardale	94·1	89·7	91·9	100 W *
Wenvoe	94·3	89·95	96·8	120 kW
Wensleydale	92·7	88·3	90·5	25 W
Whitby	94·0	89·6	91·8	40 W *
Windermere	93·0	88·6	90·8	20 W
Wrotham	93·5	89·1	91·3—S	120 kW

* Directional aerial.
† Commercial. Also broadcasts on 1295 kHz and 1594 kHz.
—S Carries stereo programmes.

UK VHF LOCAL RADIO STATIONS

	Frequency MHz	E.R.P. kW
Radio London	95·3	16·5
Medway	97·0	5·5
Oxford	95·0	4·5
Birmingham	95·6	5·5
Derby	96·5	5·5
Leicester	95·2	0·14
Nottingham	94·8	0·14
Stoke on Trent	94·6	2·5
Brighton	88·1	0·075
Solent	96·1	5·0
Bristol	95·4	5·0
Humberside	95·3	4·5
Leeds	94·6	0·14
Sheffield	88·6	0·03
Rotherham	95·05	0·009
Blackburn	96·4	1·5
Manchester	95·1	4·0
Merseyside	95·85	2·5
Durham	94·5	2·6
Newcastle	95·4	3·5
Teeside	96·6	5·0

UK BAND III STATIONS

Station	Channel	Aerial Polarization	Maximum Vision E.R.P.
Abergavenny	11	Horizontal	100 W
Ammanford (BBC Wales)	12	Horizontal	20 W
Angus	11	Vertical	50 kW *
Arfon	10	Horizontal	10 kW *
Aviemore	10	Horizontal	1 kW
Ballycastle	13	Horizontal	100 W
Bala	7	Vertical	100 W *
Bath (BBC)	6	Horizontal	250 W *
Bath	8	Horizontal	500 W *
Bedford (BBC)	10	Horizontal	3 kW
Belmont	7	Vertical	20 kW *
Belmont (BBC)	13	Vertical	20 kW *
Black Hill	10	Vertical	475 kW *
Black Mountain	9	Horizontal	100 kW *
Brecon	8	Horizontal	100 W *
Burnhope	8	Horizontal	100 kW *
Caldbeck	11	Horizontal	100 kW *
Caradon Hill	12	Vertical	200 kW *
Chillerton Down	11	Vertical	100 kW *
Croydon	9	Vertical	350 kW *
Dover	10	Vertical	100 kW *
Durris	9	Horizontal	400 kW *
Emley Moor	10	Vertical	200 kW *
Festiniog	13	Vertical	100 kW *
Fremont Point	9	Horizontal	10 kW *
Huntshaw Cross	11	Horizontal	500 W *
Lethanhill	12	Vertical	2 kW
Lichfield	8	Vertical	400 kW *
Llandovery	11	Horizontal	100 W *
Llandrindod Wells	9	Horizontal	2·5 kW *
Llanidloes (BBC Wales)	13	Horizontal	20 W *
Marlborough (BBC)	7	Horizontal	25 W
Membury	12	Horizontal	30 kW *
Mendlesham	11	Horizontal	200 kW *
Moel-y-Parc	11	Vertical	25 kW *
Moel-y-Parc (BBC Wales)	6	Vertical	20 kW
Mounteagle	12	Horizontal	50 kW *
Newhaven	6	Vertical	1 kW
Newhaven (BBC)	8	Vertical	50 W
Presely	8	Horizontal	100 kW *
Richmond Hill	8	Horizontal	10 kW *
Ridge Hill	6	Vertical	10 kW *
Rosneath	13	Vertical	100 W *
Rothesay	8	Vertical	1 kW *
Rumster Forest	8	Vertical	30 kW *
St. Hilary	10	Vertical	200 kW
St. Hilary	7	Vertical	100 kW
Sandale (BBC)	6	Horizontal	30 kW *
Sandy Heath	6	Horizontal	30 kW *
Scarborough	6	Horizontal	1 kW *
Selkirk	13	Vertical	25 kW *
Sheffield	6	Horizontal	100 W
Stockland Hill	9	Vertical	100 kW *
Strabane	8	Vertical	100 kW *
Swaledale	13	Horizontal	100 W
Wenvoe (BBC Wales)	13	Vertical	200 kW *
Whitehaven	7	Vertical	100 W *
Winter Hill	9	Vertical	100 kW
Winter Hill (BBC)	12	Vertical	125 kW

* Directional aerial. ITA unless otherwise indicated.

UK BANDS IV AND V STATIONS

UHF Station Name	Channels BBC 1	BBC 2	ITA	Fourth	Polarization	E.R.P. (kW)
Crystal Palace	26	33	23	30	Horizontal	1000
Guildford	40	46	43	50	Vertical	10
Hertford	58	64	61	54	Vertical	2
Reigate	57	63	60	53	Vertical	10
Tunbridge Wells	51	44	41	47	Vertical	10
Hemel Hempstead	51	44	41	47	Vertical	10
High Wycombe	55	62	59	65	Vertical	0·5
Sutton Coldfield	46	40	43	50	Horizontal	1000
Kidderminster	58	64	61	54	Vertical	2
Brierley Hill	57	63	60	53	Vertical	10
Bromsgrove	31	27	24	21	Vertical	10
Malvern	56	62	66	68	Vertical	10
Lark Stoke	33	26	23	29	Vertical	10
Stoke-on-Trent	31	27	24	21	Vertical	10
Winter Hill	55	62	59	65	Horizontal	500
Darwen	39	45	49	42	Vertical	0·5
Pendle Forest	22	28	25	32	Vertical	2
Haslingden	33	26	23	29	Vertical	10
Todmorden	39	45	49	42	Vertical	0·5
Saddleworth	52	45	49	42	Vertical	2
Buxton	21	27	24	31	Vertical	1
Lancaster	31	27	24	21	Vertical	10
Kendal	58	64	61	54	Vertical	2
Windermere	51	44	41	47	Vertical	0·5
Emley Moor	44	51	47	41	Horizontal	1000
Wharfedale	22	28	25	32	Vertical	2
Sheffield	31	27	24	21	Vertical	5
Skipton	39	45	49	42	Vertical	10
Chesterfield	33	26	23	29	Vertical	2
Halifax	31	27	24	21	Vertical	2
Keighley	58	64	61	54	Vertical	10
Black Hill	40	46	43	50	Horizontal	500
Wenvoe	44	51	41	47	Horizontal	500
Kilvey Hill	33	26	23	29	Vertical	10
Rhondda	33	26	23	29	Vertical	4
Mynydd Machen	33	26	23	29	Vertical	2
Maesteg	22	28	25	32	Vertical	0·5
Pontypridd	22	28	25	32	Vertical	2
Aberdare	21	27	24	31	Vertical	0·5
Merthyr Tydfil	22	28	25	32	Vertical	0·5
Bargoed	21	27	24	31	Vertical	1·5
Rhymney	57	63	60	53	Vertical	0·75
Pontypool	21	27	24	31	Vertical	1·00
Blaenavon	57	63	60	63	Vertical	0·75
Divis	31	27	24	21	Horizontal	500
Larne	39	45	49	42	Vertical	2
Kilkeel	39	45	49	42	Vertical	2
Killowen Mtn.	31	27	24	21	Vertical	0·15
Rowridge	31	24	27	21	Horizontal	500
Salisbury	57	63	60	53	Vertical	10
Ventnor	39	45	49	42	Vertical	2
Brighton	57	63	60	53	Vertical	10
Pontop Pike	58	64	61	54	Horizontal	500
Newton	33	26	23	29	Vertical	2
Fenham	31	27	24	21	Vertical	2
Weardale	51	44	41	47	Vertical	1

UK BANDS IV AND V STATIONS—*continued*

UHF Station Name	Channels BBC 1	BBC 2	ITA	Fourth	Polarization	E.R.P. (kW)
Mendip	58	64	61	54	Horizontal	500
Bath	22	28	25	32	Vertical	0·25
Bristol (Ilchester Crescent)	40	46	43	50	Vertical	0·5
Waltham	58	64	61	54	Horizontal	250
Durris	22	28	25	32	Horizontal	500
Dover	50	56	66	53	Horizontal	100
Tacolneston	62	55	59	65	Horizontal	250
West Runton	33	26	23	29	Vertical	2
Aldeburgh	33	26	23	30	Vertical	10
Sudbury	51	44	41	47	Horizontal	250
Bilsdale	33	26	29	23	Horizontal	500
Whitby	55	62	59	65	Vertical	0·25
Oxford	57	63	60	53	Horizontal	500
Llanddona	57	63	60	53	Horizontal	100
Betws-y-Coed	21	27	24	31	Vertical	2
Conway	40	46	43	50	Vertical	2·0
Bethesda	57	63	60	53	Vertical	0·03
Carmel	57	63	60	53	Horizontal	100
Belmont	22	28	25	32	Horizontal	500
Salop	33	26	23	29	Horizontal	100
Rosneath	58	64	61	54	Horizontal	50
Angus	57	63	60	53	Horizontal	100
Sandy Heath	31	27	24	21	Horizontal	1000
Midhurst	61	55	58	68	Horizontal	100
Hannington	39	45	42	66	Horizontal	250
Marlborough	22	28	25	32	Vertical	0·5
Presely	46	40	43	50	Horizontal	100
Limavady	55	62	59	65	Horizontal	100
Londonderry	51	44	41	47	Vertical	8
Caradon Hill	22	28	25	32	Horizontal	500
Stockland Hill	33	26	23	29	Horizontal	250
Blaen-Plwyf	31	27	24	21	Horizontal	100
Beacon Hill	57	63	60	53	Horizontal	100
Caldbeck	30	34	28	32	Horizontal	500
Huntshaw Cross	55	62	58	65	Horizontal	100
Heathfield	49	52	64	67	Horizontal	100
Newhaven	39	45	43	41	Vertical	2
Hastings	22	25	28	32	Vertical	1
Redruth	51	44	41	47	Horizontal	100
Moel-y-Parc	52	45	49	42	Horizontal	100
Craigkelly	31	27	24	21	Horizontal	100
Rumster Forest	21	27	24	31	Horizontal	100
Ridge Hill	22	28	25	32	Horizontal	100
Brougher Mountain	22	28	25	32	Horizontal	100
Strabane	57	63	60	53	Vertical	2
Darvel	33	26	23	29	Horizontal	100
Rosemarkie	39	45	49	42	Horizontal	100
North-West Kent	40	46	43	65	Horizontal	25
Selkirk	55	62	59	65	Horizontal	50

HORIZON DISTANCE

Horizon distance can be calculated from the formula

$$S = 1{\cdot}42\sqrt{H}$$

where $S =$ distance in miles and $H =$ height of the observer's eyes in feet above sea level.

The table which follows gives the horizon distance for various heights of aerial above sea level.

Height of Aerial Above Ground	Limit of Optical Range	Height of Aerial Above Sea Level	Limit of Optical Range
5 ft.	3·2 miles	1000 ft.	45·0 miles
20 ft.	6·4 miles	2000 ft.	63·5 miles
50 ft.	10·0 miles	3000 ft.	78·0 miles
100 ft.	14·2 miles	4000 ft.	90·0 miles
500 ft.	32·0 miles	5000 ft.	100·0 miles

GREAT CIRCLE CALCULATIONS

The distance between two places on the earth's surface may be calculated provided the latitudes and longitudes of the places are known.

Let A and B be two places on the earth's surface, as shown in Fig. 71, the angles α and β at A and B of the great circle passing through the two places and the distance D between A and B along the great circle can be calculated as follows:

let B be the place of greater latitude (nearer the pole).

L_A is the latitude of A

L_B is the latitude of B

L_D is the longitude difference between A and B.

$$\text{Then, } \tan\frac{\beta-\alpha}{2} = \cot\frac{L_D}{2}\,\frac{\sin\frac{1}{2}(L_B - L_A)}{\cos\frac{1}{2}(L_B + L_A)}$$

$$\text{and } \tan\frac{\beta+\alpha}{2} = \cot\frac{L_D}{2}\,\frac{\cos\frac{1}{2}(L_B - L_A)}{\sin\frac{1}{2}(L_B + L_A)}$$

give the values of $\dfrac{\beta-\alpha}{2}$ and $\dfrac{\beta+\alpha}{2}$

$$\text{from which } \frac{\beta+\alpha}{2} + \frac{\beta-\alpha}{2} = \beta$$

$$\text{and } \frac{\beta+\alpha}{2} - \frac{\beta-\alpha}{2} = \alpha.$$

In the above it is convenient to take northern latitudes as positive and southern as negative.

If both places are in the southern hemisphere, $L_B - L_A$ will be negative and it is simpler to refer the calculation to the South pole making suitable conversion with respect to North later if necessary.

The distance D (in degrees) along the great circle between A and B is given by:

$$\tan\frac{D}{2} = \tan\frac{L_B - L_A}{2}\cdot\frac{\sin\frac{1}{2}(\beta+\alpha)}{\cos\frac{1}{2}(\beta-\alpha)}$$

Then to convert the angular distance D (in degrees) to linear distance:

D in degrees $\times$ 69·057 = miles
D in degrees $\times$ 111·136 = kilometres

Note it is more convenient to use decimals for the minutes and seconds of degrees.

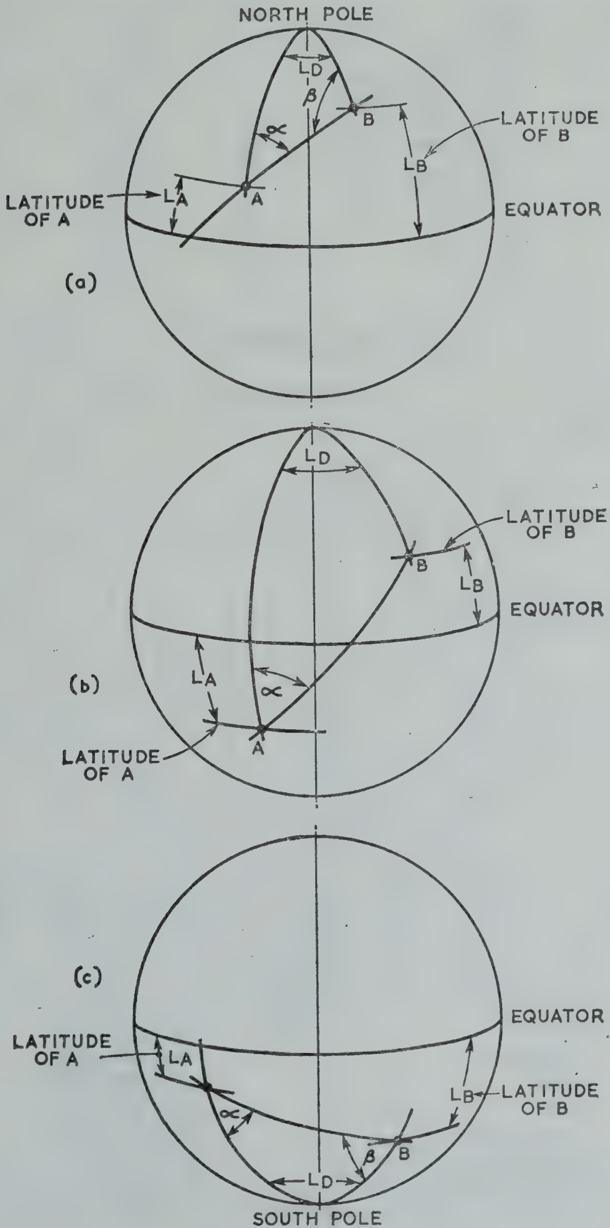


Fig. 74.

METEOROLOGICAL DATA

BEAUFORT WIND SCALE

No.	Description	Wind strength
0	Calm	less than 1 m.p.h.
1	Light air	1–3
2	Light breeze	4–7
3	Gentle breeze	8–12
4	Moderate breeze	13–18
5	Fresh Breeze	19–24
6	Strong breeze	25–31
7	Moderate gale	32–38
8	Fresh gale	39–46
9	Strong gale	47–54
10	Whole gale	55–63
11	Storm	64–75
12	Hurricane	over 75

RELATIVE HUMIDITY (%)

Dry bulb Temperature	Wet bulb temperature depression 1	2	3	4	5	6	8	10	12	14	16	18	20
0°C.	82	65	48	31	—	—	—	—	—	—	—	—	—
2	84	68	52	37	22	—	—	—	—	—	—	—	—
4	85	70	56	42	29	—	—	—	—	—	—	—	—
6	86	73	60	47	35	23	—	—	—	—	—	—	—
8	87	75	63	51	40	29	—	—	—	—	—	—	—
10	88	76	65	54	44	34	—	—	—	—	—	—	—
15	90	80	71	61	52	44	27	12	—	—	—	—	—
20	91	83	74	66	59	51	37	24	12	—	—	—	—
25	92	84	77	70	63	57	44	33	22	12	—	—	—
30	—	86	—	73	—	61	50	39	30	21	13	5	—
35	—	87	—	75	—	64	53	44	35	27	20	13	7
40	—	87	—	76	—	66	56	47	39	32	26	20	14

PRESSURE

1 inch of mercury = 33·863 millibars
1 millibar = 0·02953 inches of mercury

Inches ...	28	28·5	29	29·5	30	30·5	31	31·5
Millibars ...	948	865	982	999	1016	1032	1059	1067

VISIBILITY

Dense Fog	Less than 50 yards
Fog	50–200 yards
Slight fog	200–1000 yards
Mist	1100–2200 yards
Haze	1100–2200 yards
Poor visibility	$1\frac{1}{4}$–$2\frac{1}{2}$ miles
Moderate visibility	$2\frac{1}{2}$–$6\frac{1}{4}$ miles
Good visibility	$6\frac{1}{4}$–25 miles

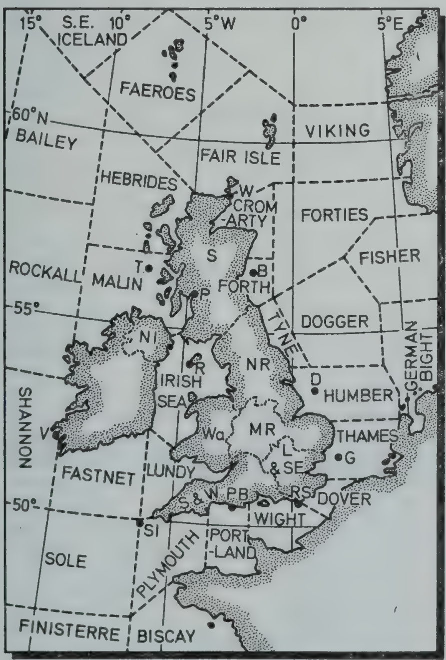
COMPARISON OF CENTIGRADE AND FAHRENHEIT THERMOMETER SCALES

Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit
— 50	— 58	+ 35	+ 95	+ 120	+ 248
— 45	— 49	+ 40	+ 104	+ 125	+ 257
— 40	— 40	+ 45	+ 113	+ 130	+ 266
— 35	— 31	+ 50	+ 122	+ 135	+ 275
— 30	— 22	+ 55	+ 131	+ 140	+ 284
— 25	— 13	+ 60	+ 140	+ 145	+ 293
— 20	— 4	+ 65	+ 149	+ 150	+ 302
— 15	+ 5	+ 70	+ 158	+ 155	+ 311
— 10	+ 14	+ 75	+ 167	+ 160	+ 320
— 5	+ 23	+ 80	+ 176	+ 165	+ 329
0	+ 32	+ 85	+ 185	+ 170	+ 338
+ 5	+ 41	+ 90	+ 194	+ 175	+ 347
+ 10	+ 50	+ 95	+ 203	+ 180	+ 356
+ 15	+ 59	+ 100	+ 212	+ 185	+ 365
+ 20	+ 68	+ 105	+ 221	+ 190	+ 374
+ 25	+ 77	+ 110	+ 230	+ 195	+ 383
+ 30	+ 86	+ 115	+ 239	+ 200	+ 392

CLOUDS

Class	Stratus Stratocumulus Nimbostratus	Cumulus Cumulonimbus	Altocumulus Altostratus	Cirrus Cirrocumulus Cirrostratus
Height	Ground/ 8000 ft.	1,500/ 8000 ft.	8000/ 20,000 ft.	20,000/ 40,000 ft.

BOUNDARIES OF SEA AND LAND AREAS, AS USED IN BBC AND POST OFFICE WEATHER FORECASTS



Stations whose latest reports are broadcast in the 5 min forecasts on Radio 2 (200 kHz) at 0030, 0630 and 1755 (daily), 1155 (Sundays) and 1355 (weekdays).

W	Wick
B	Bell Rock Lighthouse
RS	Royal Soverign Lighthouse
D	Dowsing light-vessel
G	Galloper light-vessel
PB	Portland Bill
SI	Scilly Isles
V	Valentia
R	Ronaldsway
P	Prestwick
T	Tiree

Key to land areas

S	Scotland
NR	North Region
MR	Midland Region
L & SE	London and South-east Region
S & W	South and West Region
Wa	Wales
NI	Northern Ireland

Fig. 75.

OHM'S LAW CHART

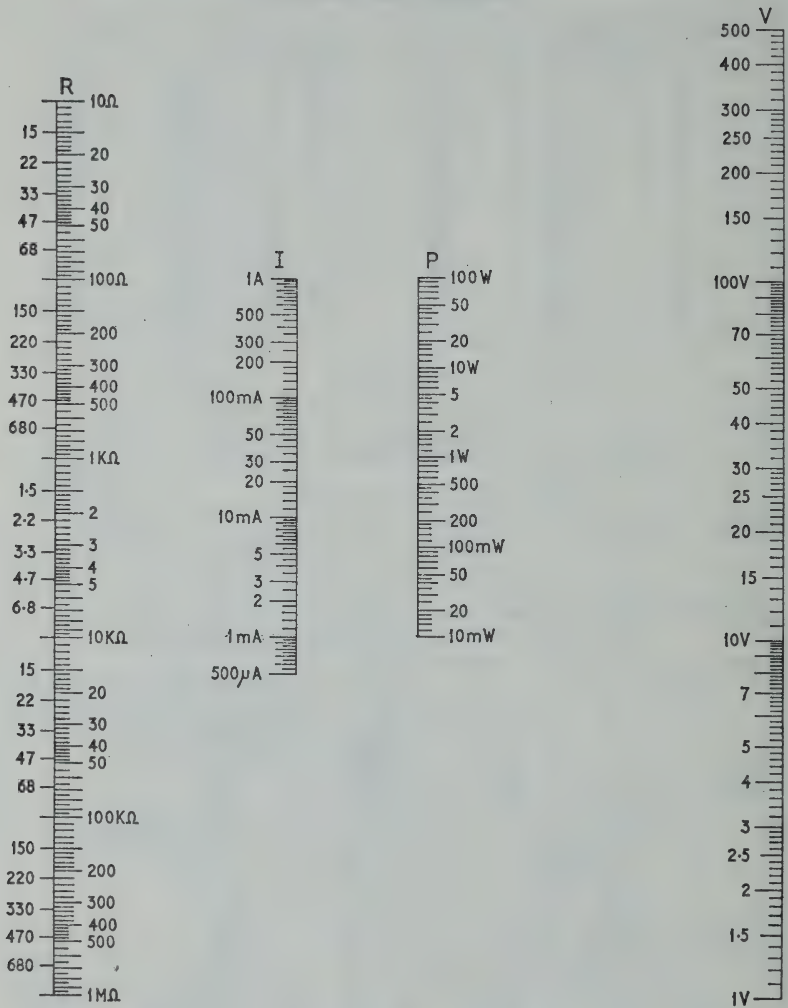


Fig. 76.

POWER, VOLTAGE, CURRENT, RESISTANCE ABAC

To use the abac, select known points on any two of the vertical scales and lay a ruler across these points so as to cut the other two scales. The points where the ruler cuts these latter scales will give the values required.

THE INTERNATIONAL SYSTEM OF UNITS

The International System (SI) comprises six basic units which are listed below, together with the symbols assigned to them. Special names have been adopted for some of the derived SI units. The definitions of these units show the relationship between them and the basic units.

BASIC SI UNITS

Quantity	Name of unit	Unit symbol
electric current	ampere	A
length	metre	m
luminous intensity	candela	cd
mass	kilogramme	kg
thermodynamic temperature	degree Kelvin	°K
time	second	s

SI UNITS WITH SPECIAL NAMES

Physical quantity	SI unit	Unit symbol
electric capacitance	farad	F = A s/V
electric charge	coulomb	C = A s
electrical potential	volt	V = W/A
electric resistance	ohm	Ω = V/A
force	newton	N = kg m/s^2
frequency	hertz *	Hz = s^{-1}
illumination	lux	lx = lm/m^2
inductance	henry	H = V s/A
luminous flux	lumen	lm = cd sr
magnetic flux	weber	Wb = Vs
magnetic flux density	tesla †	T = Wb/m^2
power	watt	W = J/s
work, energy, quantity of heat	joule	J = N m

* Hertz is equivalent to cycle per second. † Tesla is equivalent to weber per square metre.

DERIVED SI UNITS WITH COMPLEX NAMES

Physical quantity	SI unit	Unit symbol
acceleration	metre per second squared	m/s^2
angular acceleration	radian per second squared	rad/s^2
angular velocity	radian per second	rad/s
area	square metre	m^2
density (mass density)	kilogramme per cubic metre	kg/m^3
diffusion coefficient	metre squared per second	m^2/s
dynamic viscosity	newton second per metre squared	Ns/m^2
electric field strength	volt per metre	V/m
kinematic viscosity	metre squared per second	m^2/s
luminance	candela per square metre	cd/m^3
magnetic field strength	ampere per metre	A/m
pressure	newton per square metre	N/m^2
surface tension	newton per metre	N/m
thermal conductivity	watt per metre degree Kelvin	W/(m °K)
velocity	metre per second	m/s
volume	cubic metre	m^3

DEFINITIONS OF DERIVED SI UNITS HAVING SPECIAL NAMES

Electric Capacitance

The unit of electrical capacitance called the farad is the capacitance of a capacitor between the plates of which there appears a difference of potential of one volt when it is charged by a quantity of electricity equal to one coulomb.

Electric Charge

The unit of electric charge called the coulomb is the quantity of electricity transported in one second by a current of one ampere.

Electric Inductance

The unit of electric inductance called the henry is the inductance of a closed circuit in which an electromotive force of one volt is produced when the electric current in the circuit varies uniformly at the rate of one ampere per second.

Electric Potential

The unit of electric potential called the volt is the difference of potential between two points of a conducting wire carrying a constant current of one ampere, when the power dissipated between these points is equal to one watt.

Electric Resistance

The unit of electric resistance called the ohm is the resistance between two points of a conductor when a constant difference of potential of one volt, applied between these two points, produces in this conductor a current of one ampere, this conductor not being the source of any electromotive force.

Energy

The unit of energy called the joule is the work done when the point of application of a force of one newton is displaced through a distance of one metre in the direction of the force.

Force

The unit of force called the newton is that force which, when applied to a body having a mass of one kilogramme, gives it an acceleration of one metre per second squared.

Frequency

The unit of frequency called the hertz is the frequency of a periodic phenomenon of which the periodic time is one second.

Magnetic Flux

The unit of magnetic flux called the weber is the flux which, linking a circuit of one turn produces in it an electromotive force of one volt as it is reduced to zero at a uniform rate in one second.

Magnetic Flux Density

The unit of magnetic flux density called the tesla is the density of one weber of magnetic flux per square metre.

Power

The unit of power called the watt is equal to one joule per second.

Temperature

The units of Kelvin and Celsius temperature interval are identical. A temperature expressed in degrees Celsius is equal to the temperature expressed in degrees Kelvin less 273·15.

Luminous Flux

The unit of luminous flux called the lumen is the flux emitted within unit solid angle of one steradian by a point source having a uniform intensity of one candela.

Illumination

The unit of illumination called the lux is an illumination of one lumen per square metre.

VALUES OF UK UNITS IN TERMS OF SI UNITS

Area

1 in^2	$6{\cdot}4516 \times 10^{-4}$ m^2
1 ft^2	0·092 903 0 m^2
1 yd^2	0·836 127 m^2
1 $mile^2$	$2{\cdot}589\,99 \times 10^6$ m^2

Density

1 lb/in^3	$2{\cdot}767\,99 \times 10^4$ kg/m^3
1 lb/ft^3	16·0185 kg/m^3
1 lb/UK gal	99·7764 kg/m^3

Energy (work, heat)

1 ft pdl	0·042 140 1 J
1 ft lbf	1·355 82 J
1 cal	4·1868 J
1 Btu	1055·06 J

Force

1 pdl	0·138 255 N
1 lbf	4·448 22 N

Length

1 yd	0·9144 m
1 ft	0·3048 m
1 in	0·0254 m
1 mile	1609·344 m

Mass

1 lb	0·453 592 37 kg

Power

1 h.p.	745·700 W

Pressure

1 lbf/in^2	6894·76 N/m^2

Temperature

1 Rankine unit	5/9 of Kelvin unit
(= 1 Fahrenheit unit)	(= 5/9 of Celsius unit)

Velocity

1 ft/s	0·3048 m/s
1 mile/h	0·447 04 m/s

Volume

1 in^3	$1{\cdot}638\,71 \times 10^{-5}$ m^3
1 ft^3	0·028 316 8 m^3
1 (UK) gal	0·004 546 092 m^3

MULTIPLES AND SUB-MULTIPLES

The names of the multiples and sub-multiples of units are formed by means of the prefixes shown in this table.

Factor by which the unit is multiplied	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0·1 = 10^{-1}	deci	d
0·01 = 10^{-2}	centi	c
0·001 = 10^{-3}	milli	m
0·000 001 = 10^{-6}	micro	μ
0·000 000 001 = 10^{-9}	nano	n
0·000 000 000 001 = 10^{-12}	pico	p
0·000 000 000 000 001 = 10^{-15}	femto	f
0·000 000 000 000 000 001 = 10^{-18}	atto	a

CONVERSION FACTORS

To convert	into	Multiply by	Conversely Multiply by
Amps	Milliamps	10^3	10^{-3}
Amp hours	Coulombs	3600	$2{\cdot}778 \times 10^{-4}$
Amp turns per cm.	Amp turns per inch	2·54	0·3937
Atmospheres	Lb/sq. in.	14·70	0·068
B.T.U.	Foot pounds	778·3	$1{\cdot}285 \times 10^{-3}$
B.T.U.	Joules	1054·8	$9{\cdot}480 \times 10^{-3}$
B.T.U. per hour	H.P. hours	$3{\cdot}929 \times 10^{-4}$	2545
Centigrade	Fahrenheit	$\left(°C\times\frac{9}{5}\right)+32=°F$	$(°F-32)\,\frac{5}{9}=°C$
Centigrade	Kelvin	$°C+273=°K$	$°K-273=°C$
Cubic inches	Cubic feet	$5{\cdot}787 \times 10^{-4}$	1728
Cubic inches	Cubic metres	$1{\cdot}639 \times 10^{-5}$	$6{\cdot}102 \times 10^{4}$
Cycles	Kilocycles	10^{-3}	10^3
Cycles	Megacycles	10^{-6}	10^6
Degrees (angular)	Radians	$1{\cdot}745 \times 10^{-2}$	57·3
Dynes	Pounds	$2{\cdot}248 \times 10^{-6}$	$4{\cdot}448 \times 10^{5}$
Ergs	Foot pounds	$7{\cdot}376 \times 10^{-8}$	$1{\cdot}356 \times 10^{7}$
Farads	Microfarads	10^6	10^{-6}
Feet	Centimetres	30·48	$3{\cdot}281 \times 10^{-2}$
Foot-pounds	H.P. hours	$5{\cdot}05 \times 10^{-7}$	$1{\cdot}98 \times 10^{6}$
Foot pounds	Kilowatt hours	$3{\cdot}766 \times 10^{-7}$	$2{\cdot}655 \times 10^{6}$
Gausses	Lines per sq. in.	6·452	0·155
Grams	Dynes	980·7	$1{\cdot}02 \times 10^{-3}$
Grams per cm.	Pounds per in.	$5{\cdot}6 \times 10^{-3}$	178·6
Henries	Microhenries	10^6	10^{-6}
Horse power	B.T.U. per min.	42·418	$2{\cdot}357 \times 10^{-2}$
Horse power	Foot lb. per min.	$3{\cdot}3 \times 10^{4}$	$3{\cdot}03 \times 10^{-5}$
Horse power	Foot lb. per sec.	550	$1{\cdot}818 \times 10^{-3}$
Horse power	Kilowatts	0·746	1·341
Inches	Centimetres	2·54	0·3937
Inches	Mils	10^3	10^{-3}
Kilograms	Pounds (lb.)	2·205	0·454
Kilometres	Feet	3281	$3{\cdot}048 \times 10^{-4}$
Kilometres	Miles	0·621	1·609
Kilowatt hours	B.T.U.	3413	$2{\cdot}93 \times 10^{-4}$
Kilowatt hours	Joules	$3{\cdot}6 \times 10^{6}$	$2{\cdot}778 \times 10^{-7}$
Kilowatt hours	H.P. hours	1·341	0·7457
Knots	Miles per hour	1·1508	0·869
Lamberts	Candles per sq. cm	0·3183	3·142
Lamberts	Candles per sq. in.	2·054	0·4869
Lumens per sq. ft.	Foot candles	1	1
Lux	Foot candles	0·0929	10·764
Metres	Feet	3·28	0·3048
Metres	Yards	1·094	0·9144
Miles per hour	Feet per sec.	1·467	0·68182
Nepers	Decibels	8·686	0·1151
Pounds of water	Cubic feet	$1{\cdot}603 \times 10^{-2}$	62·38
Pounds of water	Gallons	0·1	10
Tons	Pounds	2240	$4{\cdot}464 \times 10^{-4}$
Watts	Ergs per sec.	10^7	10^{-7}

CGS AND MKS UNITS

Quantity	CGS Unit	CGS Symbol	MKS Unit	MKS Symbol	Ratio $\frac{MKS}{CGS}$
Acceleration ...		cm/s^2		m/s^2	10^2
Area		cm^2		m^3	10^4
Density		$g.cm^3$		$Kg.m^3$	
Force	dyne	$g.cm/s^2$ (dyn)	Newton	$Kg.m/s^2$ (N)	10^5
Inertia (moment of)		$g.cm^2$		$Kg.m^2$	10^7
Length	centimetre	cm	metre	m	10^2
Mass	gramme	g	Kilo-gramme	Kg	10^3
Momentum ...		g.cm/s		Kg.m/s	10^5
Pressure, Stress ...	barye	dyn/cm^2	pascal	N/m^2	10
Power		erg/s	watt	W (= J/s)	10^7
Time	second	s	second	s	1
Velocity		cm/s		m/s	10^2
Volume		cm^3		m^3	10^6
Work, Energy ...	erg	dyn. cm	joule	J (= Nm)	10^7

ELECTRICAL AND MAGNETIC UNITS

Quantity	Symbol	Name	MKS Unit: Defining equation	MKS Unit: Symbol	Ratio of $\frac{MKS}{CGS}$
Capacitance	C	Farad	$C=Q/V$	F	10^{-9}
Charge	Q	Coulomb	$Q=It$	As	10^{-1}
Current	I	Ampere		A	10^{-1}
Electric Field ...	E	Volt/metre	$E=V/l$	V/m	10^6
Electromotive Force	E	Volt	$P=IE$	V	10^8
Inductance	H	Henry	$M=\phi/I$	H	10^9
Magnetic Field ...	H	Ampere/metre	$H.dl=nI$	A/m	10^{-3}
Magnetic Flux ...	ϕ	Weber	$E=d\phi/dt$	Vs	10^8
Magnetic Induction...	B		$B=\phi/l^2$	$V.s/m^2$	10^4
Permeability (relative)	μ		$\mu=M/M_0$		1
Potential	V		$P=I.V$		
Resistance	R	ohm	$R=V/I$	Ω	10^9

FRACTIONS OF AN INCH WITH METRIC EQUIVALENTS

Fractions of an inch		Decimals of an inch	mm.	Fractions of an inch		Decimals of an inch	mm.
	$\frac{1}{64}$	·0156	0·397		$\frac{33}{64}$	·5156	13·097
$\frac{1}{32}$		·0312	0·794	$\frac{17}{32}$		·5313	13·494
	$\frac{3}{64}$	·0468	1·191		$\frac{35}{64}$	·5469	13·891
$\frac{1}{16}$		·0625	1·588	$\frac{9}{16}$		·5625	14·287
	$\frac{5}{64}$	·0781	1·985		$\frac{37}{64}$	·5781	14·684
$\frac{3}{32}$		·0938	2·381	$\frac{19}{32}$		·5938	15·081
	$\frac{7}{64}$	·1094	2·778		$\frac{39}{64}$	·6094	15·478
$\frac{1}{8}$		·1250	3·175	$\frac{5}{8}$		·6250	15·875
	$\frac{9}{64}$	·1406	3·572		$\frac{41}{64}$	·6406	16·272
$\frac{5}{32}$		·1563	3·969	$\frac{21}{32}$		·6563	16·668
	$\frac{11}{64}$	·1719	4·366		$\frac{43}{64}$	·6719	17·065
$\frac{3}{16}$		·1875	4·762	$\frac{11}{16}$		·6875	17·462
	$\frac{13}{64}$	·2031	5·159		$\frac{45}{64}$	·7031	17·859
$\frac{7}{32}$		·2187	5·556	$\frac{23}{32}$		·7188	18·256
	$\frac{15}{64}$	·2344	5·953		$\frac{47}{64}$	·7344	18·653
$\frac{1}{4}$		·2500	6·350	$\frac{3}{4}$		·7500	19·050
	$\frac{17}{64}$	·2656	6·747		$\frac{49}{64}$	·7656	19·447
$\frac{9}{32}$		·2813	7·144	$\frac{25}{32}$		·7813	19·843
	$\frac{19}{64}$	·2969	7·541		$\frac{51}{64}$	·7969	20·240
$\frac{5}{16}$		·3125	7·937	$\frac{13}{16}$		·8125	20·637
	$\frac{21}{64}$	·3281	8·334		$\frac{53}{64}$	·8281	21·034
$\frac{11}{32}$		·3438	8·731	$\frac{27}{32}$		·8438	21·431
	$\frac{23}{64}$	·3593	9·128		$\frac{55}{64}$	·8594	21·828
$\frac{3}{8}$		·3750	9·525	$\frac{7}{8}$		·8750	22·225
	$\frac{25}{64}$	·3906	9·922		$\frac{57}{64}$	·8906	22·622
$\frac{13}{32}$		·4063	10·319	$\frac{29}{32}$		·9062	23·019
	$\frac{27}{64}$	·4219	10·716		$\frac{59}{64}$	·9219	23·416
$\frac{7}{16}$		·4375	11·12	$\frac{15}{16}$		·9375	23·812
	$\frac{29}{64}$	·4531	11·509		$\frac{61}{64}$	·9531	24·209
$\frac{15}{32}$		·4687	11·906	$\frac{31}{32}$		·9688	24·606
	$\frac{31}{64}$	·4844	12·303		$\frac{63}{64}$	·9844	25·003
$\frac{1}{2}$		·5000	12·700			1·0000	25·400

PROPERTIES OF METALS

Material	Relative resistance	Temp. Coeff. of resistivity at 20°C.	Specific gravity	Thermal conductivity at 20°C.	Coeff. of linear expansion	Melting point °C
		$\times 10^{-4}$			$\times 10^{-6}$	
Aluminium ...	1·64	40	2·7	0·48	25·5	660
Brass	3·9	20	8·47	0·26	18·9	920
Cadmium ...	4·4	38	8·64	0·222	28·8	321
Cobalt	5·6	33	8·71		12·3	1480
Constantan ...	28·45	0·1	8·9	0·054	17·0	1210
Copper	1·00	39·3	8·89	0·918	16·7	1083
Carbon (gas) ...	29·00	—5	1·88	0·0004	5·4	3500
Eureka	28·45	0·1	8·9	—	—	—
Gold ...	1·446	34	19·32	0·705	13·9	1063
Iron (cast) ...	5·6	60	7·87	0·18	10·2	1535
Lead	12·78	42	11·37	0·083	29·1	327
Magnesium ...	2·67	40	1·74	0·376	25·4	651
Manganin ...	26·0	0·2	8·5	0·053	18·0	910
Mercury ...	55·6	9·8	13·55	0·0148	—	—38·87
Molybdenum ...	3·3	45	10·2	0·346	5·0	2622
Monel	27·8	20	8·8	0·06	14	1350
Nichrome ...	65	1·7	8·25	0·035	12·5	1350
Nickel	5·05	47	8·85	0·142	12·8	1452
Nickel silver ...	16	2·6	8·72	0·07	18·36	1110
Palladium ...	6·39	33	12·2	0·168	—	—
Phosphor bronze	5·45	—	8·9	0·15	19·0	1050
Platinum ...	6·16	38	21·4	0·166	8·9	1773
Silver	0·95	40	10·5	1·006	19·5	960·5
Steel (stainless)	52·8	—	7·9	0·069	10–11	1410
Tantalum ...	9·0	33	16·6	0·130	6·5	2850
Tin	6·7	42	7·3	0·155	21·4	231·9
Tungsten ...	3·25	45	19·2	0·476	4·44	3370
Zinc	3·4	37	7·14	0·265	26·3	419·5
Zirconium ...	2·38	44	6·4	—	—	1860

WEIGHTS OF MATERIALS

Material	Specific gravity	Weight in lbs. per		
		cu. in.	sq. inch ·001 in. thick	sq. foot ·001 in. thick
Aluminium 99·4%	2·706	0·0977	0·0000977	0·0140688
Aluminium alloy D.T.D. 249	2·7	0·0975	0·0000975	0·0140400
Aluminium alloy D.T.D. 290	2·8	0·1011	0·0001011	0·0145584
Aluminium magnesium alloy	2·68	0·0967	0·0000967	0·0139248
Aluminium manganese alloy	2·7	0·0975	0·0000975	0·0140400
Antimony	6·71	0·2422	0·0002422	0·0348768
Asbestos	2·8	0·1011	0·0001011	0·0145584
Bronze phosphor 92/8	8·8	0·3177	0·0003177	0·0457488
Bismuth	9·8	0·3538	0·0003538	0·0509472
Brass 65 35	8·47	0·3058	0·0003058	0·0440352
Bronze 2 10 88	8·78	0·3170	0·0003170	0·045648
Bronze Phosphor Sheet	8·8	0·3180	0·0003180	0·0457920
Celluloid	1·35	0·0487	0·0000487	0·0070128
Chromium	6·5	0·2347	0·0002347	0·0337968
Copper	8·93	0·3224	0·0003224	0·0464256
Cork	0·24	0·0087	0·0000087	0·0012528
Dow Metal Magnesium	1·78	0·0643	0·0000643	0·0092592
Duralumin	2·85	0·1029	0·0001029	0·0148176
Ebony wood dry	1·25	0·045	0·000045	0·00648
Elektron	1·83	0·0661	0·0000661	0·0095184
Fibre volcanized	1·41	0·0510	0·000051	0·007344
Gold cast hammered	19·32	0·6975	0·0006975	0·10044
Iridium	22·42	0·8094	0·0008094	0·1165536
Iron cast	7·2	0·2599	0·0002599	0·0374256
Iron ferrosilicon	7·01	0·2530	0·0002530	0·036432
Iron pure	7·87	0·2841	0·0002841	0·0409104
Iron sheet	7·7	0·2780	0·0002780	0·040032
Iron wrought	7·78	0·2807	0·0002807	0·0404208
Lead	11·37	0·4105	0·0004105	0·059112
Leather	0·94	0·0341	0·0000341	0·0049104

WEIGHTS OF MATERIALS—*continued*

Material	Specific gravity	Weight in lbs. per		
		cu. in.	sq. inch ·001 in. thick	sq. foot ·001 in. thick
Magnesium	1·74	0·0628	0·0000628	0·0090432
Magnesium aluminium alloy 7% ...	2·63	0·0949	0·0000949	0·0136656
Manganese	7·42	0·2679	0·0002679	0·0385776
Mercury	13·6	0·4910		
Mica	2·8	0·1011	0·0001011	0·0145584
Micarta	1·24	0·0446	0·0000446	0·0064224
Molybdenum	10·2	0·3682	0·0003682	0·0530208
Monel Metal cast	8·8	0·3177	0·0003177	0·0457488
Monel Metal rolled	8·9	0·3212	0·0003212	0·0462528
Nickel	8·8	0·3177	0·0003177	0·0457488
Nickel alloy 45%	8·0	0·2888	0·0002888	0·0415872
Paper...	0·93	0·0336	0·0000336	0·0048384
Pewter	7·49	0·2703	0·0002703	0·0389232
Platinum sheet	21·54	0·7776	0·0007776	0·1119744
Platinum wire	21·04	0·7595	0·0007595	0·109368
Rubber soft	0·95	0·0341	0·0000341	0·0049104
Rubber hard ebonite	1·15	0·0416	0·0000416	0·0059904
Silicon	2·42	0·0874	0·0000874	0·0125856
Silver...	10·78	0·3890	0·000389	0·056016
Silver German or Nickel ...	8·75	0·3160	0·000316	0·045504
Steel crucible sheet	7·9	0·2853	0·0002853	0·0410832
Steel machinery	7·81	0·2818	0·0002818	0·0405792
Steel rolled sheet	7·85	0·2833	0·0002833	0·0407952
Steel stainless	8·4	0·3033	0·0003033	0·0436752
Steel tool	7·9	0·2853	0·0002853	0·0410832
Steel 2½% silicon transformer grade	7·42	0·268	0·000268	0·038592
Tin	7·30	0·2635	0·0002635	0·037944
Tungsten	18·77	0·6776	0·0006776	0·0975744
Vanadium	5·5	0·1986	0·0001986	0·0285984
Zinc cast	7·11	0·2567	0·0002567	0·0369648
Zinc rolled	7·2	0·26	0·000260	0·03744

SYNTHETIC INSULATING MATERIALS

	ELECTRICAL					MECHANICAL			GENERAL			
	Power factor at 1 MHz	Permit-ivity at 1 MHz	Surface resistivity	Volume resistivity	Electric strength at 90°C	Tensile strength (UTS)	Cross breaking strength	Impact strength	Water absorption	Plastic yield m/max°C	Max operating temper.	Filler
	$^3\tan\delta$		MΩ	MΩ	V/mil	lbs/in²	lbs/in²		mg.		°C	
Thermo-setting												
Polyester-fastcure												
High impact	0·018	4·5	10^5	10^7	200	6,000	20,000	4	100	2 at 160	100	glass fibre
general purpose	0·014	5·0	10^6	10^8	250	3,000	7,000	0·12	130	3 at 160	100	mineral
general purpose (imp.)	0·016	4·5	10^6	10^7	260	4,200	10,000	0·25	160	3 at 160	100	mineral
Diallyl phthalate												
High impact	—	—	10^8	10^7	250	5,000	12,000	3·0	150	—	110	glass fibre
general purpose	0·05	5·5	10^5	10^8	200	3,000	6,000	0·12	80	—	110	mineral
general purpose (imp.)	0·04	5·0	5×10^6	10^9	250	4,500	6,500	0·14	55	—	110	mineral
Polyester dough	0·02	6·0	10^6	10^7	200	7,000	—	7·0	35	—	—	glass fibre
General purpose	0·02	6·0	10^7	10^7	240	7,000	—	7·0	25	—	—	glass fibre
Melamine Formaldehyde	0·06	7·0	10^5	3×10^4	130	3,000	5,000	0·1	30	6 at 180	110	—
Phenolic												
Electrical-Type L4	0·015	5·5	10^7	10^7	200	4,000	8,300	0·09	15	6 at 100	90	Mica
Type L	0·025	5·8	10^6	10^6	150	4,000	8,300	0·10	20	6 at 140	100	Mica
Type L1	0·025	4·8	3×10^5	3×10^5	75	6,000	10,000	0·14	27	6 at 100	90	Nylon
Type L2	0·035	5·0	10^5	10^5	100	6,500	10,000	0·12	27	6 at 140	100	Nylon & cellulose
Type L3	0·040	5·5	3×10^5	3×10^5	130	4,000	7,500	0·12	20	6 at 140	100	Nylon & mica
Type HD	0·050	6·0	$1{\cdot}6 \times 10^3$	2×10^5	90	6,500	9,500	0·11	75	6 at 140	100	Wood flour
Mechanical Type MS	—	—	8×10^2	10^3	30	6,000	9,500	0·25	80	6 at 140	100	Ground cotton
Type MHS	—	—	2×10^2	10^3	30	5,400	9,200	0·55	85	6 at 140	100	cotton
Type HS	—	—	25	10^3	30	5,500	9,200	0·75	110	6 at 140	100	Fabric
Heat Resistant HR	0·058	7·3	5×10^3	5×10^3	120	3,500	7,000	0·07	37	6 at 180	140	Asbestos
Silicone Moulding												
(dry)	0·004	3·5	28×10^8	80×10^6	100–200	4,400	14,000	15	0·10	—	230	—
(wet)	0·020	3·6	28×10^8	$0{\cdot}09 \times 10^6$	100–200	1,300	5,000	11	0·13	—	230	—
Thermo Plastic												
Polyamides (nylon) (dry)												
general purpose 66GP	0·05	4·0	10^6	10^6	220	11,000	—	—	—	—	80	—
general purpose 6GP	—	—	10^6	10^6	220	10,000	—	—	—	—	80	—
general purpose 11GP	—	—	10^6	10^6	220	8,000	—	—	—	—	80	—
general purpose 610GP	—	—	10^6	10^6	220	8,000	—	—	—	—	80	—

Weather resistant 66 W	—	—	10^6	10^6	220	11,500	—	—	—	—	80	—
Weather resistant 6 W	—	—	10^6	10^6	220	10,500	—	—	—	—	80	—
Weather resistant 11 W	—	—	10^6	10^6	220	8,500	—	—	—	—	80	—
Hot Air 66 HL	—	—	10^6	10^6	220	11,000	—	—	—	—	105	—
Hot Air 6 HL	—	—	10^6	10^6	220	9,000	—	—	—	—	105	—
Hot Air 11 HL	—	—	10^6	10^6	220	8,000	—	—	—	—	105	—
Polyethylene												
low density	0·00015/ 0·0003	2·35	10^8	3×10^9	1000 at 20°C	1,000/ 1,500	—	3	3	—	70	—
high density	0·00015/ 0·003	2·35	10^8	3×10^9	1000 at 20°C	3,700	—	1–10	3	—	95	—
Polypropylene	0·0005	2·2	10^8	10^8	600	4,500	—	1	0·03	—	90	—
Polystyrene										softening		
Normal Type A	0·0005	2·7	10^8	10^8	400	4,000	5,400	0·12	5	100	70	—
Type B	0·0005	2·7	10^8	10^8	400	4,000	5,400	0·12	5	90	60	—
Type C	0·0005	2·7	10^8	10^8	400	4,000	5,400	0·12	5	85	55	—
Type D	0·0007	2·7	10^8	10^8	400	—	—	—	—	75	50	—
Toughened Type 1	0·001	2	10^8	10^8	400	3,000	—	—	20	80	—	—
Type 2	0·001	2	10^8	10^8	400	3,500	—	—	15	85	—	—
Type 3	0·001	2	10^8	10^8	400	4,000	—	—	20	90	—	—
P.T.F.E.	0·00025	2·12	10^8	10^{11}	500 edgewise	2,000	—	4	1	7150	250	—
Laminates												
Phenolic Board												
Paper Base for RF Type H	0·038	5	5×10^4	—	25kV	8,000	10,000	0·08	13	—	100	—
Paper Base for RF Type L	0·045	5·8	5×10^2	—	25kV	8,000	12,000	0·15	32	—	100	—
Paper Base non RF Type P3	—	—	10^3	—	20kV	8,000	12,000	0·15	32	—	100	—
Paper Base non RF Type P4	—	—	10^4	—	20kV	8,000	10,000	0·08	13	—	100	—
Fabric Base for RF Type IA	0·04	5·8	10^6	—	50kV	—	10,000	0·3	65	—	100	—
Fabric Base for RF Type IB	0·045	5·8	10^5	—	25kV	8,000	13,000	0·45	65	—	100	—
Fabric Base for non RF Type 2A	—	—	5×10^3	—	20kV	—	15,000	0·45	65	—	100	—
Asbestos Paper non RF	—	—	20	—	3kV	12,000	—	0·45	55	—	130	—
Epoxide resin glass fabric	0·035	5·5	10^3	—	15kV	26,000	35,000	3	12	—	140	—
Melamine resin glass fabric	—	—	50	—	6kV	15,000	12,000	3	118	—	130	—
Silicone resin glass fabric (S1)	0·005	4	10^4	—	13kV	12,000	15,000	13	10	—	200	—
Silicone resin glass fabric (S2)	0·01	4·5	100	—	8kV	14,000	16,000	4	20	—	200	—

INSULATING MATERIALS

Material	Dielectric Constant at 50 c/s	Power Factor			Dielectric Strength V/0·001″	Resistance Ohms per cm.	Softening Temp. °C.	Coeff. of expansion — 10^6 per °C.
		50 Hz	1 MHz	100 MHz				
Air (N.P.)	1	—	—	—	19·8–22·8	—	—	—
Cellulose Acetate ...	6–8	6	10	—	250–1000	$4·5 \times 10^{10}$	70	160
Cellulose Nitrate ...	4–7	5–15	7–10	—	300–780	$2–30 \times 10^{10}$	85	90–160
Fibre	2·5–5	6–9	5	5	150–180	5×10^{9}	130	25
Glass, Crown	6·2	—	1	—	500	—	1100	8·9
Glass, Photographic ...	7·5	—	0·8–1	—	—	—	—	—
Glass, Pyrex	4·5	—	0·2–0·7	0·54	335	10^{14}	600	3·2
Mica	2·5–8	0·2	0·2–6	—	—	2×10^{17}	—	—
Mica, Clear Indian ...	7–7·3	0·03–0·05	0·02–0·03	0·03	600–1500	5×10^{12}	1200	3–7
Micalex	6–8	0·64	0·21	0·22	350	—	348	8–9
Paper	2–2·6	—	—	—	1250	—	—	—
Paraffin Wax	2·25	0·02	0·02	0·02	203–305	10^{16}	MP56	—
Pyrophillite	5·2	—	0·2–0·7	0·36	500	$1·3 \times 10^{15}$	—	—
Quartz	3·5–4·2	0·09	0·02	0·02	200	$10^{14}–10^{18}$	1430	0·45
Rubber, hard	2–3·5	1	0·5–1	—	450	$10^{12}–10^{15}$	70	70–80
Shellac	2·5–4	0·6–2·5	0·9–3·1	3	900	10^{16}	85	—
Urea Formaldehyde ...	5–7	3–5	2·8	5	300–550	$10^{12}–10^{13}$	200	70
Vinyl Resins	4	—	1·7	—	400–500	10^{14}	—	70
Wood, Dry Oak ...	2·5–6·8	—	4·2	—	—	—	—	—

CERAMIC INSULATING MATERIALS

MATERIAL	DIELECTRIC		Power factor at 1 MHz	Volume resistivity at 20°C (ohms/cm³)	THERMAL		Working temperature (°C)	Water absorption (%)	Specific gravity	STRENGTH	
	Strength at 50 c/s (V/0·001″)	Constant at 1 MHz			Conductivity at 20°C (CGS units)	Expansion at 0–200°C (ppm/°C)				Tensile (lb/sq. in)	Compressive (lb/sq. in)
Alumina (95%) ...	500	9·6	0·006	10^{16}	0·054	6·3	1400	0	3·72	18300	240000
Alumina (99·5%) ...	200	9·0	0·0005	10^{16}	0·06	7·6	1600	0	3·9	35000	300000
Aluminium silicate ...	80	5·3	0·01	10^{14}	0·003	3·3	1100	2–3	2·3	2500	40000
Boron nitrite	900	4·15	0·0002	10^{14}	0·064	10·0	1700	0·17	2·1	5500	45000
Beryllium oxide ...	400	7·0	0·0004	10^{13}	0·02	7·0	1800	0	3·01	17500	200000
Corderite	100	5·0	0·004	10^{14}	0·003	2·2	1250	10–15	2·1	3500	30000
Fosterite	250	6·2	0·0004	10^{14}	0·0024	10·0	1000	0	2·8	10000	85000
Lithium-aluminium silicate	300	6·0	0·005	10^{14}	0·005	1·2	1000	0–2	2·0	350	4000
Magnesium silicate ...	100	5·8	0·0003	10^{14}	0·005	10·7	1250	2–3	2·8	2500	90000
Porcelain	300	5·6	0·0055	$10^{13}–10^{14}$	0·0024	4–6	1000	0–0·5	2·4	4250	110000
Steatite	230	6·0	0·0021	$10^{14}–10^{15}$	0·0035	8	1000	0	2·6	8000	120000
Zircon	220	8·8	0·001	10^{14}	0·015	4·5	1200	0	3·7	12000	100000

STANDARD WIRE GAUGE AND STANDARD DRILL SIZES

Standard wire gauge	Standard drill size in. mm.	Decimal inch equivalent	Nearest obsolete number drill	Standard wire gauge	Standard drill size in. mm.	Decimal inch equivalent	Nearest obsolete number drill
50		0·0010		23		0·0240	
49		0·0012			0·62	0·0244	
48		0·0016			0·65	0·0256	72, 71
47		0·0020			0·68	0·0268	
46		0·0024			0·70	0·0276	70
45		0·0028		22		0·0280	
44		0·0032			0·72	0·0283	
43		0·0036			0·75	0·0295	69
42		0·0040			0·78	0·0307	
41		0·0044			$\frac{1}{32}$	0·0312	68
40		0·0048			0·80	0·0315	
39		0·0052		21		0·0320	
38		0·0060			0·82	0·0323	67
37		0·0068			0·85	0·0335	66
36		0·0076			0·88	0·0346	
35		0·0084			0·90	0·0354	65
34		0·0092		20		0·0360	
33		0·0100			0·92	0·0362	64
32		0·0108			0·95	0·0374	63
31		0·0116			0·98	0·0386	62
30		0·0124			1·00	0·0394	61,60
	0·32	0·0126		19		0·0400	
29		0·0136			1·05	0·0413	59,58
	0·35	0·0138	80		1·10	0·0433	57
28		0·0148			1·15	0·0453	
	0·38	0·0150	79		$\frac{3}{64}$	0·0469	56
	$\frac{1}{64}$	0·0156			1·20	0·0472	
	0·40	0·0157	78	18		·0480	
27		0·0164			1·25	0·0492	
	0·42	0·0165			1·30	0·0512	55
	0·45	0·0177	77		1·35	0·0532	
26		0·0180			1·40	0·0551	54
	0·48	0·0189	76	17		0·0560	
	0·50	0·0197			1·45	0·0571	
25		0·0200			1·50	0·0591	53
	0·52	0·0205	75		1·55	0·0610	
	0·55	0·0217			$\frac{1}{16}$	0·0625	
24		0·0220			1·60	0·0630	52
	0·58	0·0228	74	16		0·0640	
	0·60	0·0236	73		1·65	0·0650	

STANDARD WIRE GAUGE AND STANDARD DRILL SIZES—*continued*

Standard wire gauge	Standard drill size in. mm.	Decimal inch equivalent	Nearest obsolete number drill	Standard wire gauge	Standard drill size in. mm.	Decimal inch equivalent	Nearest obsolete number drill
	1·70	0·0669	51		3·40	0·1339	
	1·75	0·0689			3·50	0·1378	29
	1·80	0·0709	50		$\frac{9}{64}$	0·1406	28
15		0·0720			3·60	0·1417	
	1·85	0·0728	49	9		0·1440	
	1·90	0·0748			3·70	0·1457	27, 26
	1·95	0·0768	48		3·80	0·1496	25
	$\frac{5}{64}$	0·0781			3·90	0·1535	24, 23
	2·00	0·0787	47		$\frac{5}{32}$	0·1562	
14		0·0800			4·00	0·1575	22, 21
	2·05	0·0807	46	8		0·1600	
	2·10	0·0827	45		4·10	0·1614	20
	2·15	0·0846			4·20	0·1654	19
	2·20	0·0866	44		4·30	0·1693	18
	2·25	0·0886	43		$\frac{11}{64}$	0·1719	
	2·30	0·0906			4·40	0·1732	17
13		0·0920		7		0·1760	
	2·35	0·0925			4·50	0·1772	16
	$\frac{3}{32}$	0·0938	42		4·60	0·1811	15, 14
	2·40	0·0945			4·70	0·1850	13
	2·45	0·0965	41		$\frac{3}{16}$	0·1875	
	2·50	0·0984	40		4·80	0·1890	12
	2·55	0·1004	39	6		0·1920	
	2·60	0·1024	38		4·90	0·1929	11, 10
12		0·1040			5·00	0·1968	9
	2·65	0·1043	37		5·10	0·2008	8, 7
	2·70	0·1063	36		$\frac{13}{64}$	0·2031	
	2·75	0·1083			5·20	0·2047	6, 5
	$\frac{7}{64}$	0·1094			5·30	0·2087	4
	2·80	0·1102	35, 34	5		0·2120	
	2·85	0·1122	33		5·40	0·2126	3
	2·90	0·1142			5·50	0·2165	
11		0·1160			$\frac{7}{32}$	0·2188	
	2·95	0·1161	32		5·60	0·2205	2
	3·00	0·1181	31		5·70	0·2244	
	3·10	0·1220			5·80	0·2283	1
	$\frac{1}{8}$	0·1250		4		0·2320	
	3·20	0·1260			5·90	0·2323	
10		0·1280			$\frac{15}{64}$	0·2344	A
	3·30	0·1299	30		6·00	0·2362	B

STANDARD WIRE GAUGE AND STANDARD DRILL SIZES—*continued*

Standard wire gauge	Standard drill size in.	Standard drill size mm.	Decimal inch equivalent	Nearest obsolete letter drill
		6·10	0·2402	C
		6·20	0·2441	D
		6·30	0·2480	
	$\frac{1}{4}$		0·2500	E
3		6·40	0·2520	
		6·50	0·2559	F
		6·60	0·2598	G
		6·70	0·2638	
	$\frac{17}{64}$		0·2656	H
		6·80	0·2677	
		6·90	0·2717	I
		7·00	0·2756	J
2			0·2760	
		7·10	0·2795	
	$\frac{9}{32}$		0·2812	K
		7·20	0·2835	
		7·30	0·2874	
		7·40	0·2913	L
		7·50	0·2953	M
	$\frac{19}{64}$		0·2969	
		7·60	0·2992	
1			0·3000	
		7·70	0·3032	N
		7·80	0·3071	
		7·90	0·3110	
	$\frac{5}{16}$		0·3125	
		8·00	0·3150	O
		8·10	0·3189	
		8·20	0·3228	P
0			0·3240	
		8·30	0·3268	
	$\frac{21}{64}$		0·3281	
		8·40	0·3307	Q
		8·50	0·3346	
		8·60	0·3386	R
		8·70	0·3425	
	$\frac{11}{32}$		0·3438	
		8·80	0·3465	S
00			0·3480	
		8·90	0·3504	

Standard wire gauge	Standard drill size in.	Standard drill size mm.	Decimal inch equivalent	Nearest obsolete letter drill
		9·00	0·3543	
		9·10	0·3583	T
	$\frac{23}{64}$		0·3594	
		9·20	0·3622	
		9·30	0·3661	U
		9·40	0·3701	
3/0			0·3720	
		9·50	0·3740	
	$\frac{3}{8}$		0·3750	V
		9·60	0·3780	
		9·70	0·3819	
		9·80	0·3858	W
		9·90	0·3898	
	$\frac{25}{64}$		0·3906	
		10·00	0·3937	
		10·10	0·3976	X
4/0			0·4000	
		10·20	0·4016	
		10·30	0·4055	Y
	$\frac{13}{32}$		0·4062	
		10·40	0·4094	
		10·50	0·4134	Z
		10·60	0·4173	
		10·70	0·4213	
	$\frac{27}{64}$		0·4219	
		10·80	0·4252	
		10·90	0·4291	
5/0			0·4320	
		11·00	0·4331	
		11·10	0·4370	
	$\frac{7}{16}$		0·4375	
		11·20	0·4409	

Drill sizes proceed thus: $\frac{1}{2}$ in. to 2 in. in $\frac{1}{64}$ in. steps; 12·7 mm. to 14 mm. in 0·1 mm steps; 14 mm. to 25 mm. in 0·25 mm. steps; 25 mm. to 50·5 mm. in 0·5 mm. steps.

TAPPING AND CLEARANCE DRILL SIZES FOR B.S.F. AND B.S.W. THREADS

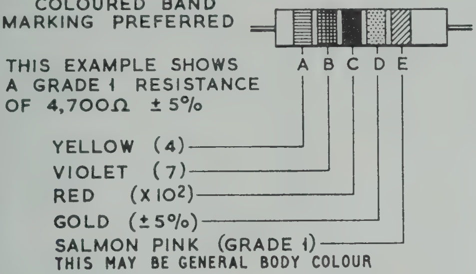
Tapping sizes for		Clearance for	Standard drill size		Decimal inch equivalent
B.S.F.	B.S.W.	B.S.W.–B.S.F.	inches	mm.	
	$\frac{3}{16}$			3·80	0·1496
		$\frac{3}{16}$		4·90	0·1929
	$\frac{1}{4}$		$\frac{13}{64}$		0·2031
$\frac{1}{4}$				5·40	0·2126
		$\frac{1}{4}$		6·50	0·2559
	$\frac{5}{16}$			6·60	0·2598
$\frac{5}{16}$				6·80	0·2677
	$\frac{3}{8}$		$\frac{5}{16}$		0·3125
		$\frac{5}{16}$		8·20	0·3228
$\frac{3}{8}$			$\frac{21}{64}$		0·3281
	$\frac{7}{16}$			9·40	0·3701
$\frac{7}{16}$				9·70	0·3819
		$\frac{3}{8}$		9·80	0·3858
	$\frac{1}{2}$		$\frac{27}{64}$		0·4219
$\frac{1}{2}$			$\frac{7}{16}$		0·4375
		$\frac{7}{16}$	$\frac{29}{64}$		0·4531
$\frac{9}{16}$			$\frac{1}{2}$		0·5000
		$\frac{1}{2}$	$\frac{33}{64}$		0·5156
	$\frac{5}{8}$		$\frac{17}{32}$		0·5312
$\frac{5}{8}$				14·00	0·5512
		$\frac{9}{16}$	$\frac{37}{64}$		0·5781
	$\frac{3}{4}$		$\frac{21}{32}$		0·6562
		$\frac{5}{8}$	$\frac{41}{64}$		0·640
$\frac{3}{4}$			$\frac{43}{64}$		0·6719
	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{49}{64}$		0·7656
$\frac{7}{8}$				20·00	0·7874
	1		$\frac{7}{8}$		0·8750
		$\frac{7}{8}$	$\frac{57}{64}$		0·8906
			$\frac{29}{32}$		0·9062
		1	$1\frac{1}{64}$		1·0156

B.A. SCREWS

Size	Diameter		Threads per inch	Pitch		Hole size			
						Clearance		Tapping	
	inches	mm.		in.	mm.	Size	No.	Size	No.
0	0·2362	6·0	25·4	0·0394	1·0	0·242	C	0·196	9
1	0·2087	5·3	28·2	0·0354	0·9	0·213	3	0·173	17
2	0·185	4·7	31·4	0·0319	0·81	0·1935	10	0·152	24
3	0·1614	4·1	34·8	0·0287	0·73	0·1695	18	0·128	30
4	0·1417	3·6	38·5	0·026	0·66	0·1495	25	0·116	32
5	0·126	3·2	43·0	0·0232	0·59	0·136	29	0·104	37
6	0·1102	2·8	47·9	0·0209	0·53	0·120	31	0·089	43
7	0·0984	2·5	52·9	0·0189	0·48	0·1065	36	0·081	46
8	0·0866	2·2	59·1	0·0169	0·43	0·0985	42	0·07	50
9	0·0748	1·9	65·1	0·0154	0·39	0·081	46	0·0595	53
	0·0669	1·7	72·6	0·0138	0·35	0·073	49	0·055	54

COLOUR CODE FOR RESISTORS AND CAPACITORS

FIG. 1
COLOURED BAND MARKING PREFERRED



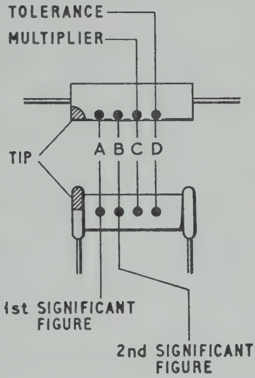


FIG. 4
DOT SYSTEM FOR CAPACITORS (TUBULAR)

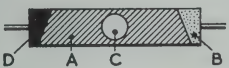


FIG. 2
BODY, TIP AND SPOT MARKING

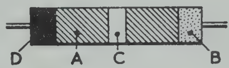
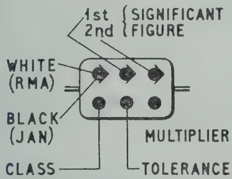


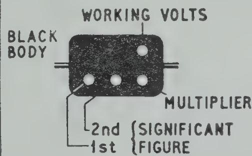
FIG. 3
BODY, TIP AND CENTRAL BAND MARK'G

AMERICAN R.M.A. JAN AND COMMERCIAL
Markings for Moulded Mica Capacitors

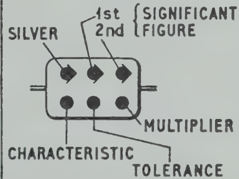
CURRENT STANDARD CODE



MOULDED FLAT CAPACITOR COMMERCIAL CODE



JAN CODE CAPACITOR



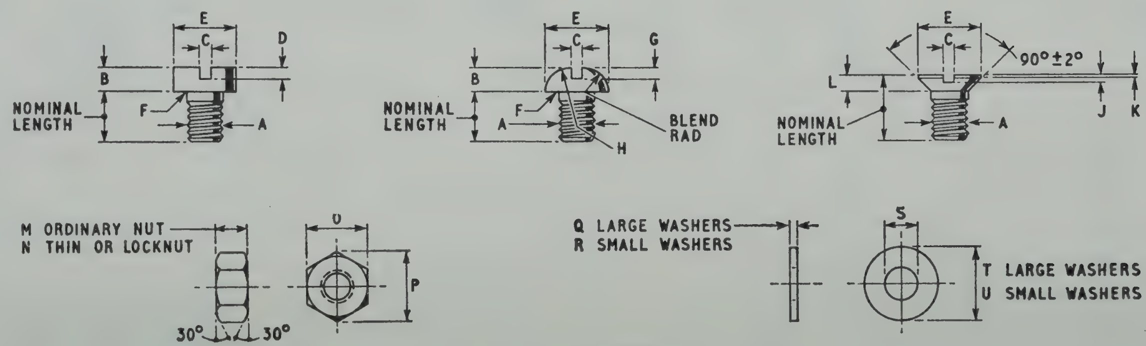
Colour	Value in ohms or pF for Cols. A, B & C				Band D. (Tolerance rating)			Capacitors Band E. Temp. Coefficient per 10⁶ per °C.
	Band A First Figure	Band B Second Figure	Band C (Multiplier) Resistors (ohms)	Band C (Multiplier) Capacitors (pF)	Resistors	Ceramic Capacitors Up to 10pF	Ceramic Capacitors Over 10pF	
Black	—	0	1	1	—	2pF	±20%	0
Brown	1	1	10	10	±1%	0·1pF	± 1%	−30
Red	2	2	100	100	±2%	—	± 2%	−80
Orange	3	3	1,000	1,000	—	—	±2·5%	−150
Yellow	4	4	10,000	10,000	—	—	—	−220
Green	5	5	100,000	—	—	0·5pF	± 5%	−330
Blue	6	6	1,000,000	—	—	—	—	−470
Violet	7	7	10,000,000	—	—	—	—	−750
Grey	8	8	100,000,000	0·01μF	—	0·25pF	—	+30
White	9	9	1,000,000,000	0·1μF	—	1pF	±10%	+100
Silver	—	—	0·01	—	±10%	—	—	—
Gold	—	—	0·1	—	± 5%	—	—	—
Salmon Pink	—	—	—	—	—	—	—	—

Standard tolerances for resistors are as follows: wire-wound type: 1%, 2%, 5%, 10%; composition type, grade 1: 1%, 2%, 5%, grade 2: 5%, 10%, 20% (20% is indicated by a fourth (D band) colour). Grade 1 high-stability composition resistors are distinguished by a salmon-pink fifth ring or body colour. (Reference: B.S.1852: 1952 B.S.I.)

DIMENSIONS OF BRITISH ASSOCIATION SCREWS, NUTS AND WASHERS SELECTED FROM B.S .57 : 1951

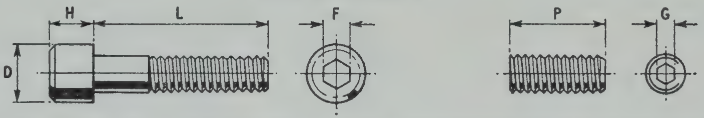
	B.A. No.	T.P.I.	A dia. max.		B		C		D	E		F rad.	G	H rad.	J	K	L
			mm.	in.	Max.	Tol.	Max.	Tol.	Nom.	Max.	Tol.	Max.	Nom.	Approx.	Nom.	Max.	Nom.
Pre-ferred	2	31·3	4·7	·185	·130	−7	·052	−8	·058	·319	−10	·015	·071	·319	·036	·010	·077
	4	38·5	3·6	·142	·101	−6	·040	−6	·045	·252	−10	·010	·056	·252	·031	·010	·065
	6	47·9	2·8	·110	·078	−5	·033	−6	·035	·194	−10	·010	·043	·194	·024	·009	·051
	8	59·1	2·2	·087	·063	−4	·030	−6	·027	·157	−10	·010	·035	·157	·021	·008	·043
	10	72·6	1·7	·067	·045	−4	·024	−5	·020	·112	− 5	·007	·025	·112	·016	·007	·030
	12	90·7	1·3	·051	·038	−3	·020	−5	·017	·095	− 5	·005	—	—	·014	·006	·028
Second choice	0	25·4	6·0	·236	·167	−8	·064	−8	·075	·413	−10	·015	·092	·413	·045	·010	·099
	1	28·2	5·3	·209	·148	−7	·058	−8	·066	·366	−10	·015	·081	·366	·041	·010	·089
	3	34·8	4·1	·161	·113	−6	·047	−8	·051	·283	−10	·015	·062	·283	·033	·010	·071
	5	43·1	3·2	·126	·088	−5	·040	−6	·040	·221	−10	·010	·048	·221	·028	·010	·058

Dimensions in inches except where otherwise stated. Tolerance columns given in ·001 inch units.



	B.A. No.	M		N		O		P	Q		R		S		T		U	
		Max.	Tol.	Max.	Tol.	Max.	Tol.	Max.	S.W.G.	in.	S.W.G.	in.	Max.	Tol.	Max.	Tol.	Max.	Tol.
Pre-ferred	2	·167	−10	·123	−10	·324	−5	·37	18	·048	21	·032	·202	−5	·500	−5	·391	−5
	4	·135	−10	·094	−10	·248	−5	·29	19	·040	22	·028	·157	−5	·378	−5	·301	−5
	6	·105	−10	·073	−10	·193	−4	·22	20	·036	23	·024	·123	−5	·288	−5	·233	−5
	8	·082	−7	·058	−7	·152	−3	·18	25	·020	25	·020	·099	−5	·228	−5	·185	−5
	10	·064	−7	—	—	·117	−3	·14	27	·016	—	—	·078	−5	·176	−5	—	—
	12	·049	−5	—	—	·090	−2	·10	—	—	—	—	—	—	—	—	—	—
Second choice	0	·213	−10	·157	−10	·413	−5	·48	17	·056	19	·040	·256	−5	·625	−5	·500	−5
	1	·188	−10	·139	−10	·365	−5	·42	18	·048	20	·036	·228	−5	·565	−5	·443	−5
	3	·153	−10	·108	−10	·282	−5	·33	19	·040	22	·028	·177	−5	·432	−5	·341	−5
	5	·120	−10	·084	−10	·220	−4	·25	20	·036	23	·024	·140	−5	·335	−5	·268	−5

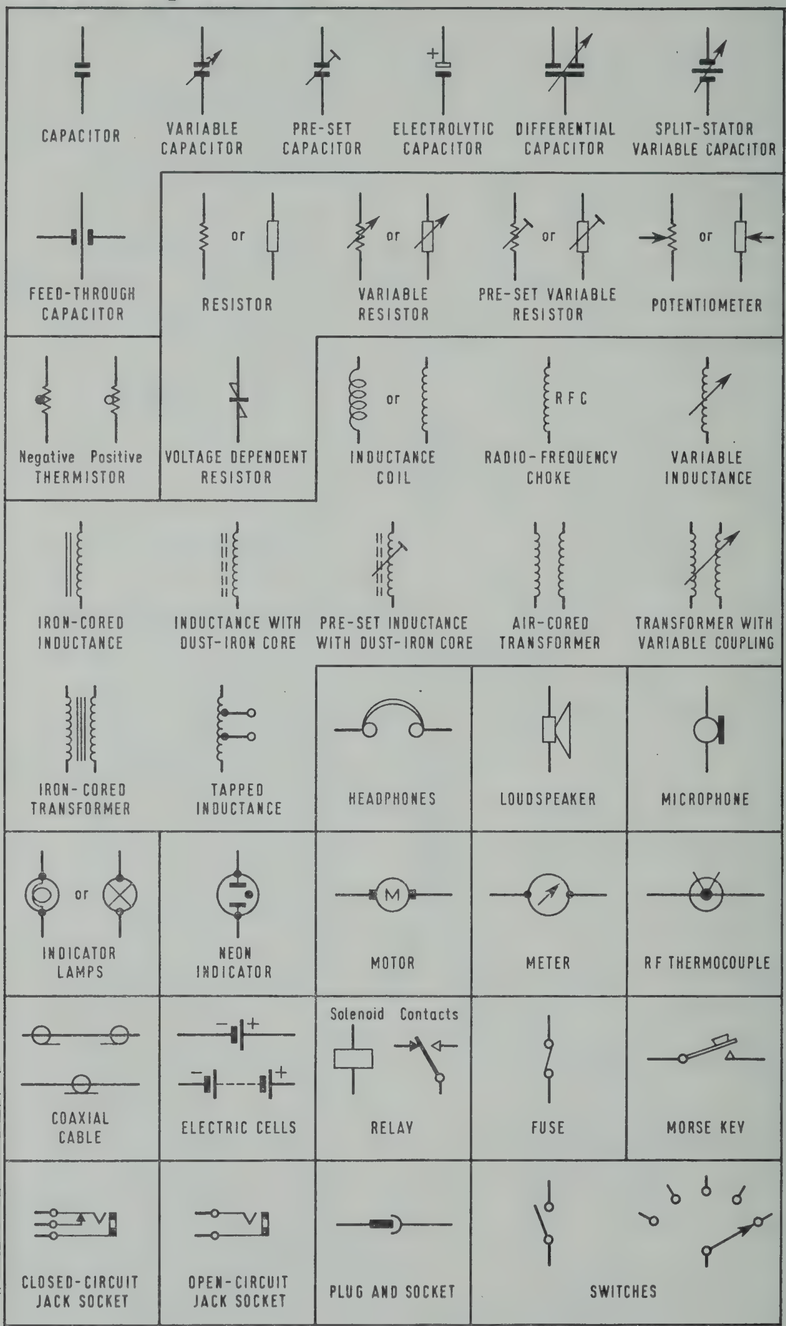
SOCKET SCREWS



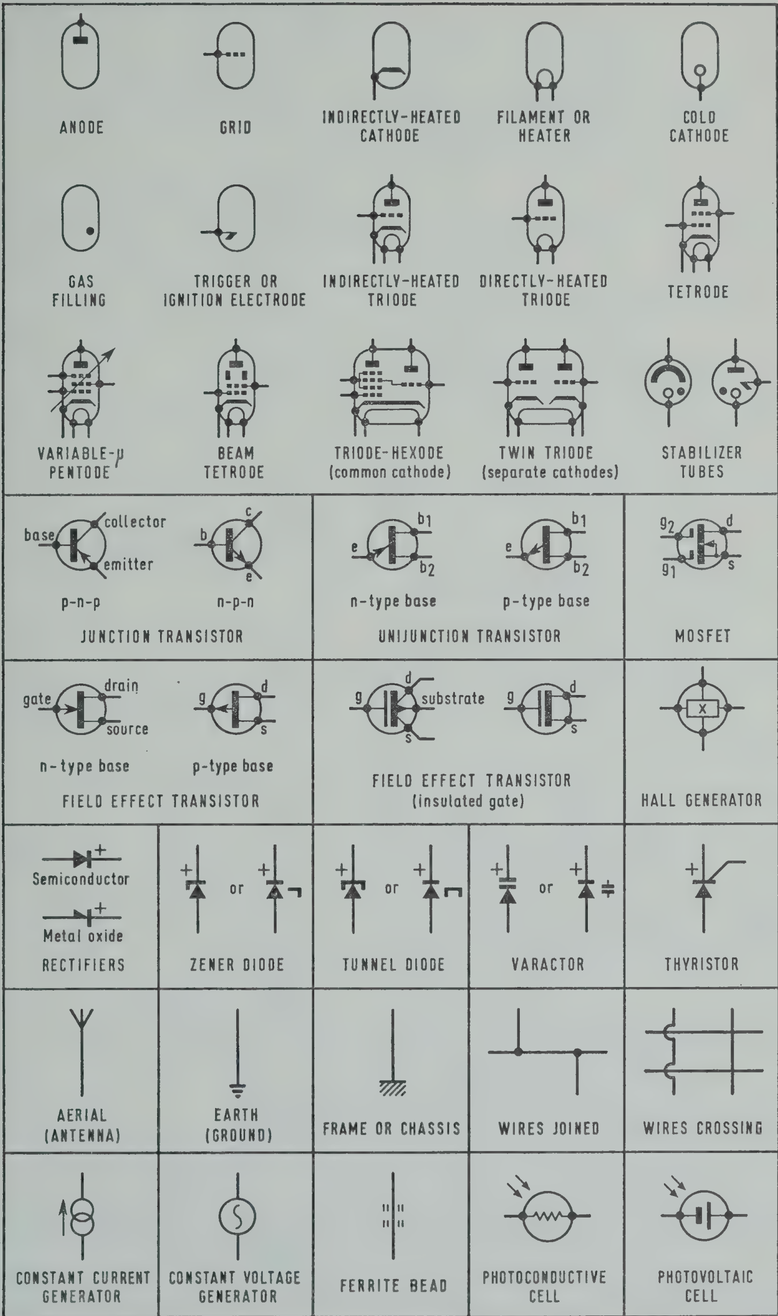
SIZE	CAP SCREWS				SET SCREWS	
	D	H	F	L	G	P
6 B.A.					0·050	
5 B.A.					1/16"	
4 B.A.	0·248	0·142	1/8"	1/4"–3/4"	1/16"	3/16"–3/4"
3 B.A.	0·282	0·161	1/8"	3/8"–1"	5/64"	3/16"–1"
2 B.A.	0·324	0·185	5/32"	3/8"–1 1/2"	3/32"	3/16"–1 1/4"
1 B.A.	0·365	0·209	3/16"	3/8"–2"	3/32"	3/16"–1 1/4"
0 B.A.	0·413	0·236	7/32"	3/8"–3"	1/8"	3/16"–2"
3/16"	5/16"	3/16"	5/32"	3/8"–2"	3/32"	3/16"–1 1/4"
1/4"	3/8"	1/4"	3/16"	3/8"–3"	1/8"	3/16"–2"

SIZE	CAP SCREWS				SET SCREWS		PIPE PLUGS	
	D	H	F	L	G	P	G	P
5/16"	7/16"	5/16"	7/32"	3/8"–3 1/2"	5/32"	1/4"–2"		
3/4" 1/8" gas	9/16"	3/8"	5/16"	1/2"–5"	3/16"	1/4"–2 1/2"	3/16"	3/8"
7/16"	5/8"	7/16"	5/16"	1/2"–4"	7/32"	3/8"–2 1/2"		
1/2" 1/4" gas	3/4"	1/2"	3/8"	1/2"–6"	1/4"	3/8"–3"	1/4"	1/2"
5/8" 3/8" gas	7/8"	5/8"	1/2"	1"–6"	5/16"	1/2"–3"	5/16"	9/16"
3/4" 1/2" gas	1"	3/4"	9/16"	1 1/4"–6"	3/8"	5/8"–3"	3/8"	9/16"
7/8" 5/8" gas	1 1/8"	7/8"	9/16"	1 3/4"–6"	1/2"	3/4"–3"		
1" 3/4" gas	1 5/16"	1"	5/8"	2"–6"	9/16"	1"–3"	9/16"	5/8"
1" gas							5/8"	3/4"

Circuit symbols ....



Circuit symbols ....



SINFO signal-reporting code for C.W.

	S	I	N	F	O
Rating scale	Signal strength	Interference (QRM)	Noise (QRN)	Fading	Over-all readability (QRK)
5	Excellent	Nil	Nil	Nil	Excellent
4	Good	Slight	Slight	Slight	Good
3	Fair	Moderate	Moderate	Moderate	Fair
2	Poor	Severe	Severe	Severe	Poor
1	Barely audible	Extreme	Extreme	Extreme	Unusable

SINPFEMO reports for phone operation

	S	I	N	P	F	E	M	O
Rating scale	Signal strength	Interference (QRM)	Noise (QRN)	Propagation disturbance	Frequency of fading	Modulation quality	Modulation Depth	Over-all rating
5	Excellent	Nil	Nil	Nil	Nil	Excellent	Maximum	Excellent
4	Good	Slight	Slight	Slight	Slow	Good	Good	Good
3	Fair	Moderate	Moderate	Moderate	Moderate	Fair	Fair	Fair
2	Poor	Severe	Severe	Severe	Fast	Poor	Poor or nil	Poor
1	Barely audible	Extreme	Extreme	Extreme	Very fast	Very poor	Continuously over-modulated	Unusable

FUNDAMENTAL FREQUENCIES OF FT241 CRYSTALS

Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency
0	370·370	20·0	13	394·444	21·3	26	418·519	22·6	39	442·593	23·9	52	466·667	25·2	65	490·741	26·5
1	372·222	20·1	14	396·296	21·4	27	420·370	22·7	40	444·444	24·0	53	468·519	25·3	66	492·593	26·6
2	374·074	20·2	15	398·148	21·5	28	422·222	22·8	41	446·296	24·1	54	470·370	25·4	67	494·444	26·7
3	375·926	20·3	16	400·000	21·6	29	424·074	22·9	42	448·148	24·2	55	472·222	25·5	68	496·296	26·8
4	377·778	20·4	17	401·852	21·7	30	425·926	23·0	43	450·000	24·3	56	474·074	25·6	71	501·852	27·1
5	379·630	20·5	18	403·704	21·8	31	427·778	23·1	44	451·852	24·4	57	475·926	25·7	72	503·704	27·2
6	381·481	20·6	19	405·556	21·9	32	429·630	23·2	45	453·704	24·5	58	477·778	25·8	73	505·556	27·3
7	383·333	20·7	20	407·407	22·0	33	431·481	23·3	46	455·556	24·6	59	479·630	25·9	74	507·407	27·4
8	385·185	20·8	21	409·259	22·1	34	433·333	23·4	47	457·407	24·7	60	481·481	26·0	75	509·259	27·5
9	387·037	20·9	22	411·111	22·2	35	435·185	23·5	48	459·259	24·8	61	483·333	26·1	76	511·111	27·6
10	388·889	21·0	23	412·963	22·3	36	437·037	23·6	49	461·111	24·9	62	485·185	26·2	77	512·963	27·7
11	390·741	21·1	24	414·815	22·4	37	438·889	23·7	50	462·963	25·0	63	487·037	26·3	78	514·815	27·8
12	392·593	21·2	25	416·667	22·5	38	440·741	23·8	51	464·815	25·1	64	488·889	26·4	79	516·667	27·9

Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency	Channel No.	Fund. frequency	Marked frequency
270	375·000	27·0	295	409·722	29·5	320	444·444	32·0	348	483·333	34·8	375	520·833	37·5
271	376·388	27·1	296	411·111	29·6	321	445·833	32·1	349	484·722	34·9	376	522·222	37·6
272	377·777	27·2	297	412·500	29·7	322	447·222	32·2	350	486·111	35·0	377	523·611	37·7
273	379·166	27·3	298	413·888	29·8	323	448·611	32·3	351	487·500	35·1	378	525·000	37·8
274	380·555	27·4	299	415·277	29·9	324	450·000	32·4	352	488·888	35·2	379	526·388	37·9
275	381·944	27·5	300	416·666	30·0	325	451·388	32·5	353	490·277	35·3	380	527·777	38·0
276	383·333	27·6	301	418·055	30·1	326	452·777	32·6	354	491·666	35·4	381	529·166	38·1
277	384·722	27·7	302	419·444	30·2	330	458·333	33·0	355	493·055	35·5	382	530·555	38·2
278	386·111	27·8	303	420·833	30·3	331	459·722	33·1	356	494·444	35·6	383	531·944	38·3
279	387·500	27·9	304	422·222	30·4	332	461·111	33·2	357	495·833	35·7	384	533·333	38·4
280	388·888	28·0	305	423·611	30·5	333	462·500	33·3	358	497·222	35·8	385	534·722	38·5
281	390·277	28·1	306	425·000	30·6	334	463·888	33·4	359	498·611	35·9	386	536·111	38·6
282	391·666	28·2	307	426·388	30·7	335	465·277	33·5	361	501·388	36·1	387	537·500	38·7
283	393·055	28·3	308	427·777	30·8	336	466·666	33·6	362	502·777	36·2	388	538·888	38·8
284	394·444	28·4	309	429·166	30·9	337	468·055	33·7	363	504·166	36·3	389	540·277	38·9
285	395·833	28·5	310	430·555	31·0	338	469·444	33·8	365	506·944	36·5			
286	397·222	28·6	311	431·944	31·1	339	470·833	33·9	366	508·333	36·6			
287	398·611	28·7	312	433·333	31·2	340	472·222	34·0	367	509·722	36·7			
288	400·000	28·8	313	434·722	31·3	341	473·611	34·1	368	511·111	36·8			
289	401·388	28·9	314	436·111	31·4	342	475·000	34·2	369	512·500	36·9			
290	402·777	29·0	315	437·500	31·5	343	476·388	34·3	370	513·888	37·0			
291	404·166	29·1	316	438·888	31·6	344	477·777	34·4	371	515·277	37·1			
292	405·555	29·2	317	440·277	31·7	345	479·166	34·5	372	516·666	37·2			
293	406·944	29·3	318	441·666	31·8	346	480·555	34·6	373	518·055	37·3			
294	408·333	29·4	319	443·055	31·9	347	481·944	34·7	374	519·444	37·4			

NOTE

These two ranges may be interchanged for closer sidebands.
Fundamental frequencies in kHz.
Marked requencies in MHz.

FREQUENCIES OF FT241 CRYSTALS FOR S.S.B. FILTERS

Channel No.	Harmonic Type*	Marked Channel (MHz)	Fund. Freq. (kHz)	Difference in freq. (kHz)
288	B	28·8	400·000	
16	A	21·6	400·000	
289	B	28·9	401·389	1·389
17	A	21·7	401·851	0·462
290	B	29·0	402·777	0·926
18	A	21·8	403·703	0·926
291	B	29·1	404·166	0·463
19	A	21·9	405·555	1·389
292	B	29·2	405·555	0
293	B	29·3	406·944	1.389
20	A	22·0	407·407	0·463
294	B	29·4	408·333	0·926
21	A	22·1	409·259	0·926
295	B	29·5	409·722	0·463
22	A	22·2	411·111	1·389
296	B	29·6	411·111	0
297	B	29·7	412·500	1.389
23	A	23·3	412·963	0·463
298	B	29·8	413·888	0·925
24	A	22·4	414·814	0·926
299	B	29·9	415·277	0·463
25	A	22·5	416·666	1·389
300	B	30·0	416·666	0
301	B	30·1	418·055	1·389
26	A	22·6	418·518	0·463
302	B	30·2	419·444	0·926
27	A	22·7	420·370	0·926
303	B	30·3	420·833	0·463
28	A	22·8	422·222	1·389
304	B	30·4	422·222	0
305	B	30·5	423·611	1·389
29	A	22·9	424·074	0·463
306	B	30·6	425·000	0·926
30	A	23·0	425·926	0·926
307	B	30·7	426·888	0·462
31	A	23·1	427·777	1·389
308	B	30·8	427·777	0
309	B	30·9	429·166	1·389
32	A	23·2	429·629	0·463
310	B	31·0	430·555	0·926
33	A	23·3	431·481	0·926
311	B	31·1	431·944	0·463

Channel No.	Harmonic Type*	Marked Channel (MHz)	Fund. Freq. (kHz)	Difference in. freq. (kHz)
34	A	23·4	433·333	1·389
312	B	31·2	433·333	0
313	B	31·3	434·722	1·389
35	A	23·5	435·185	0·463
314	B	31·4	436·111	0·926
36	A	23·6	437·037	0·926
315	B	31·5	437·500	0·463
37	A	23·7	438·888	1·388
316	B	31·6	438·888	0
317	B	31·7	440·277	1·389
38	A	23·8	440·740	0·463
318	B	31·8	441·666	0·926
39	A	23·9	442·592	0·926
319	B	31·9	443·055	0·463
40	A	24·0	444·444	1·389
320	B	32·0	444·444	0
321	B	32·1	445·833	1·389
41	A	24·1	446·296	0·463
322	B	32·2	447·222	0·926
42	A	24·2	448·148	0·926
323	B	32·3	448·611	0·463
43	A	24·3	450·000	1·389
324	B	32·4	450·000	0
325	B	32·5	451·389	1·389
44	A	24·4	451·852	0·463
326	B	32·6	452·777	0·925
45	A	24·5	453·703	0·926
327	B	32·7	454·166	0·463
46	A	24·6	455·555	1·389
328	B	32·8	455·555	0
329	B	32·9	456·944	1·389
47	A	24·7	457·407	0·463
330	B	33·0	458·333	0·926
48	A	24·8	459·259	0·926
331	B	33·1	459·722	0·463
49	A	24·9	461·111	1·389
332	B	33·2	461·111	0
333	B	33·3	462·500	1·389
50	A	25·0	462·962	0·462
334	B	33·4	463·888	0·926
51	A	25·1	464·814	0·926
335	B	33·5	465·277	0·463

Channel No.	Harmonic Type*	Marked Channel (MHk)	Fund. Freq. (kHz)	Difference in freq. (kHz)
52	A	25·2	466·666	1·389
336	B	33·6	466·666	0
337	B	33·7	468·055	1·389
53	A	25·3	468·518	0·463
338	B	33·8	469·444	0·926
54	A	25·4	470·370	0·926
339	B	33·9	470·833	0·463
55	A	25·5	472·222	1·389
340	B	34·0	472·222	0
341	B	34·1	473·611	1·389
56	A	25·6	474·074	0·463
342	B	34·2	475·000	0·926
57	A	25·7	475·925	0·925
343	B	34·3	476·388	0·463
58	A	25·8	477·777	1·389
344	B	34·4	477·777	0
345	B	34·5	479·166	1·389
59	A	25·9	479·629	0·463
346	B	34·6	480·555	0·926
60	A	26·0	481·481	0·926
347	A	34·7	481·944	0·463
61	A	26·1	483·333	1·389
348	B	34·8	483·333	0
349	B	34·9	484·722	1·389
62	A	26·2	485·185	0·463
350	B	35·0	486·111	0·926
63	A	26·3	487·037	0·926
351	B	35·1	487·500	0·463
64	A	26·4	488·888	1·388
352	B	35·2	488·888	0
353	B	35·3	490·277	1·390
65	A	26·5	490·740	0·463
354	B	35·4	491·666	0·926
66	A	26·6	492·592	0·926
355	B	35·5	493·055	0·463
67	A	26·7	494·444	1·389
356	B	35·6	494·444	0
357	B	35·7	495·833	1·389
68	A	26·8	496·296	0·463
358	B	35·8	497·222	0·926
69	A	26·9	498·148	0·926
359	B	35·9	498·611	0·463
70	A	27·0	500·000	3·389
360	B	36·0	500·000	0

*A 54th harmonic; B 72nd harmonic

	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	10
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	11
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

	0	1	2	3	4		6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8383	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	8284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

HYPERBOLIC OR NAPERIAN LOGARITHMS

	0	1	2	3	4	5	6	7	8	9	Mean Differences 1	2	3	4	5	6	7	8	9
1·0	0·0000	0099	0198	0296	0392	0488	0583	0677	0770	0862	10	19	29	38	48	57	67	76	86
1·1	0·0953	1044	1133	1222	1310	1398	1484	1570	1655	1740	9	17	26	35	44	52	61	70	78
1·2	0·1823	1906	1989	2070	2151	2231	2311	2390	2469	2546	8	16	24	32	40	48	56	64	72
1·3	0·2624	2700	2776	2852	2927	3001	3075	3148	3221	3293	7	15	22	30	37	44	52	59	67
1·4	0·3365	3436	3507	3577	3646	3716	3784	3853	3920	3988	7	14	21	28	35	41	48	55	62
1·5	0·4055	4121	4187	4253	4318	4383	4447	4511	4574	4637	6	13	19	26	32	39	45	52	58
1·6	0·4700	4762	4824	4886	4947	5008	5068	5128	5188	5247	6	12	18	24	30	36	42	48	55
1·7	0·5306	5365	5423	5481	5539	5596	5653	5710	5766	5822	6	11	17	24	29	34	40	46	51
1·8	0·5878	5933	5988	6043	6098	6152	6206	6259	6313	6366	5	11	16	22	27	32	38	43	49
1·9	0·6419	6471	6523	6575	6627	6678	6729	6780	6831	6881	5	10	15	20	26	31	36	41	46
2·0	0·6931	6981	7031	7080	7129	7178	7227	7275	7324	7372	5	10	15	20	24	29	34	39	44
2·1	0·7419	7467	7514	7561	7608	7655	7701	7747	7793	7839	5	9	14	19	23	28	33	37	42
2·2	0·7885	7930	7975	8020	8065	8109	8154	8198	8242	8286	4	9	13	18	22	27	31	36	40
2·3	0·8329	8372	8416	8459	8502	8544	8587	8629	8671	8713	4	9	13	17	21	26	30	34	38
2·4	0·8755	8796	8838	8879	8920	8961	9002	9042	9083	9123	4	8	12	16	20	24	29	33	37
2·5	0·9163	9203	9243	9282	9322	9361	9400	9439	9478	9517	4	8	12	16	20	24	27	31	35
2·6	0·9555	9594	9632	9670	9708	9746	9783	9821	9858	9895	4	8	11	15	19	23	26	30	34
2·7	0·9933	9969	·0006	0043	0080	0116	0152	0188	0225	0260	4	7	11	15	18	22	25	29	33
2·8	1·0296	0332	0367	0403	0438	0473	0508	0543	0578	0613	4	7	11	14	18	21	25	28	32
2·9	1·0647	0682	0716	0750	0784	0818	0852	0886	0919	0953	3	7	10	14	17	20	24	27	31
3·0	1·0986	1019	1053	1086	1119	1151	1184	1217	1249	1282	3	7	10	13	16	20	23	26	30
3·1	1·1314	1346	1378	1410	1442	1474	1506	1537	1569	1600	3	6	10	13	16	19	22	25	29
3·2	1·1632	1663	1694	1725	1756	1787	1817	1848	1878	1909	3	6	9	12	15	18	22	25	28
3·3	1·1939	1969	2000	2030	2060	2090	2119	2149	2179	2208	3	6	9	12	15	18	21	24	27
3·4	1·2238	2267	2296	2326	2355	2384	2413	2442	2470	2499	3	6	9	12	15	17	20	23	26
3·5	1·2528	2556	2585	2613	2641	2669	2698	2726	2754	2782	3	6	8	11	14	17	20	23	25
3·6	1·2809	2837	2865	2892	2920	2947	2975	3002	3029	3056	3	5	8	11	14	16	19	22	25
3·7	1·3083	3110	3137	3164	3191	3218	3244	3271	3297	3324	3	5	8	11	13	16	19	21	24
3·8	1·3350	3376	3403	3429	3455	3481	3507	3533	3558	3584	3	5	8	10	13	16	18	21	23
3·9	1·3610	3635	3661	3686	3712	3737	3762	3788	3813	3838	3	5	8	10	13	15	18	20	23
4·0	1·3863	3888	3913	3938	3962	3987	4012	4036	4061	4085	2	5	7	10	12	15	17	20	22
4·1	1·4110	4134	4159	4183	4207	4231	4255	4279	4303	4327	2	5	7	10	12	14	17	19	22
4·2	1·4351	4375	4398	4422	4446	4469	4493	4516	4540	4563	2	5	7	9	12	14	16	19	21
4·3	1·4586	4609	4633	4656	4679	4702	4725	4748	4770	4793	2	5	7	9	12	14	16	18	21
4·4	1·4816	4839	4861	4884	4907	4929	4951	4974	4996	5019	2	5	7	9	11	14	16	18	20
4·5	1·5041	5063	5085	5107	5129	5151	5173	5195	5217	5239	2	4	7	9	11	13	15	18	20
4·6	1·5261	5282	5304	5326	5347	5369	5390	5412	5433	5454	2	4	6	9	11	13	15	17	19
4·7	1·5476	5497	5518	5539	5560	5581	5602	5623	5644	5665	2	4	6	8	11	13	15	17	19
4·8	1·5686	5707	5728	5748	5769	5790	5810	5831	5851	5872	2	4	6	8	10	12	14	16	19
4·9	1·5892	5913	5933	5953	5974	5994	6014	6034	6054	6074	2	4	6	8	10	12	14	16	18
5·0	1·6094	6114	6134	6154	6174	6194	6214	6233	6253	6273	2	4	6	8	10	12	14	16	18
5·1	1·6292	6312	6332	6351	6371	6390	6409	6429	6448	6467	2	4	6	8	10	12	14	16	18
5·2	1·6487	6506	6525	6544	6563	6582	6601	6620	6639	6658	2	4	6	8	10	11	13	15	17
5·3	1·6677	6696	6715	6734	6752	6771	6790	6808	6827	6845	2	4	6	7	9	11	13	15	17
5·4	1·6864	6882	6901	6919	6938	6956	6974	6993	7011	7029	2	4	5	7	9	11	13	15	17

Hyperbolic or Naperian Logarithms of 10^{+n}

n	1	2	3	4	5	6	7	8	9
$\log_e 10^n$	2·3026	4·6052	6·9078	9·2103	11·5129	13·8155	16·1181	18·4207	20·7233

HYPERBOLIC OR NAPERIAN LOGARITHMS—*continued*

	0	1	2	3	4	5	6	7	8	9	Mean Differences 1	2	3	4	5	6	7	8	9
5·5	1·7047	7066	7084	7102	7120	7138	7156	7174	7192	7210	2	4	5	7	9	11	13	14	16
5·6	1·7228	7246	7263	7281	7299	7317	7334	7352	7370	7387	2	4	5	7	9	11	12	14	16
5·7	1·7405	7422	7440	7457	7475	7492	7509	7527	7544	7561	2	3	5	7	9	10	12	14	16
5·8	1·7579	7596	7613	7630	7647	7664	7681	7699	7716	7733	2	3	5	7	9	10	12	14	15
5·9	1·7750	7766	7783	7800	7817	7834	7851	7867	7884	7901	2	3	5	7	8	10	12	13	15
6·0	1·7918	7934	7951	7967	7984	8001	8017	8034	8050	8066	2	3	5	7	8	10	12	13	15
6·1	1·8083	8099	8116	8132	8148	8165	8181	8197	8213	8229	2	3	5	6	8	10	11	13	15
6·2	1·8245	8262	8278	8294	8310	8326	8342	8358	8374	8390	2	3	5	6	8	10	11	13	14
6·3	1·8405	8421	8437	8453	8469	8485	8500	8516	8532	8547	2	3	5	6	8	9	11	13	14
6·4	1·8563	8579	8594	8610	8625	8641	8656	8672	8687	8703	2	3	5	6	8	9	11	12	14
6·5	1·8718	8733	8749	8764	8779	8795	8810	8825	8840	8856	2	3	5	6	8	9	11	12	14
6·6	1·8871	8886	8901	8916	8931	8946	8961	8976	8991	9006	2	3	5	6	8	9	11	12	14
6·7	1·9021	9036	9051	9066	9081	9095	9110	9125	9140	9155	1	3	4	6	7	9	10	12	13
6·8	1·9169	9184	9199	9213	9228	9242	9257	9272	9286	9301	1	3	4	6	7	9	10	12	13
6·9	1·9315	9330	9344	9359	9373	9387	9402	9416	9430	9445	1	3	4	6	7	9	10	12	13
7·0	1·9459	9473	9488	9502	9516	9530	9544	9559	9573	9587	1	3	4	6	7	9	10	11	13
7·1	1·9601	9615	9629	9643	9657	9671	9685	9699	9713	9727	1	3	4	6	7	8	10	11	13
7·2	1·9741	9755	9769	9782	9796	9810	9824	9838	9851	9865	1	3	4	6	7	8	10	11	12
7·3	1·9879	9892	9906	9920	9933	9947	9961	9974	9988	·0001	1	3	4	5	7	8	10	11	12
7·4	2·0015	0028	0042	0055	0069	0082	0096	0109	0122	0136	1	3	4	5	7	8	9	11	12
7·5	2·0149	0162	0176	0189	0202	0215	0229	0242	0255	0268	1	3	4	5	7	8	9	11	12
7·6	2·0281	0295	0308	0321	0334	0347	0360	0375	0386	0399	1	3	4	5	7	8	9	10	12
7·7	2·0412	0425	0438	0451	0464	0477	0490	0503	0516	0528	1	3	4	5	6	8	9	10	12
7·8	2·0541	0554	0567	0580	0592	0605	0618	0631	0643	0656	1	3	4	5	6	8	9	10	11
7·9	2·0669	0681	0694	0707	0719	0732	0744	0757	0769	0782	1	3	4	5	6	8	9	10	11
8·0	2·0794	0807	0819	0832	0844	0857	0869	0882	0894	0906	1	3	4	5	6	7	9	10	11
8·1	2·0919	0931	0943	0956	0968	0980	0992	1005	1017	1029	1	2	4	5	6	7	9	10	11
8·2	2·1041	1054	1066	1078	1090	1102	1114	1126	1138	1150	1	2	4	5	6	7	9	10	11
8·3	2·1163	1175	1187	1199	1211	1223	1235	1247	1258	1270	1	2	4	5	6	7	8	10	11
8·4	2·1282	1294	1306	1318	1330	1342	1353	1365	1377	1389	1	2	4	5	6	7	8	9	11
8·5	2·1401	1412	1424	1436	1448	1459	1471	1483	1494	1506	1	2	4	5	6	7	8	9	11
8·6	2·1518	1529	1541	1552	1564	1576	1587	1599	1610	1622	1	2	3	5	6	7	8	9	10
8·7	2·1633	1645	1656	1668	1679	1691	1702	1713	1725	1736	1	2	3	5	6	7	8	9	10
8·8	2·1748	1759	1770	1782	1793	1804	1815	1827	1838	1849	1	2	3	5	6	7	8	9	10
8·9	2·1861	1872	1883	1894	1905	1917	1928	1939	1950	1961	1	2	3	4	6	7	8	9	10
9·0	2·1972	1983	1994	2006	2017	2028	2039	2050	2061	2072	1	2	3	4	6	7	8	9	10
9·1	2·2083	2094	2105	2116	2127	2138	2148	2159	2170	2181	1	2	3	4	5	6	8	9	10
9·2	2·2192	2203	2214	2225	2235	2246	2257	2268	2279	2289	1	2	3	4	5	6	8	9	10
9·3	2·2300	2311	2322	2332	2343	2354	2364	2375	2386	2396	1	2	3	4	5	6	7	9	10
9·4	2·2407	2418	2428	2439	2450	2460	2471	2481	2492	2502	1	2	3	4	5	6	7	8	10
9·5	2·2513	2523	2534	2544	2555	2565	2576	2586	2597	2607	1	2	3	4	5	6	7	8	9
9·6	2·2618	2628	2638	2649	2659	2670	2680	2690	2701	2711	1	2	3	4	5	6	7	8	9
9·7	2·2721	2732	2742	2752	2762	2773	2783	2793	2803	2814	1	2	3	4	5	6	7	8	9
9·8	2·2824	2834	2844	2854	2865	2875	2885	2895	2905	2915	1	2	3	4	5	6	7	8	9
9·9	2·2925	2935	2946	2956	2966	2976	2986	2996	3006	3016	1	2	3	4	5	6	7	8	9
10·0	2·3026																		

Hyperbolic or Naperian Logarithms of 10^{-n}

n	1	2	3	4	5	6	7	8	9
$\log_e 10^{-n}$	3·6974	5·3948	7·0922	10·7897	12·4871	14·1845	17·8819	19·5793	21·2767

NATURAL SINES, TANGENTS, COTANGENTS AND COSINES

To Ten Minutes of Arc

°	′	Sine	Tan.	Cotan.	Cosine	′	°	°	′	Sine	Tan.	Cotan.	Cosine	′	°
0	0	0·0000	0·0000	Infinite	1·0000	0	90	11	0	0·1908	0·1944	5·1446	0·9816	0	79
	10	0·0029	0·0029	343·7737	1·0000	50			10	0·1937	0·1974	5·0658	0·9811	50	
	20	0·0058	0·0058	171·8854	1·0000	40			20	0·1965	0·2004	4·9894	0·9805	40	
	30	0·0087	0·0087	114·5887	1·0000	30			30	0·1994	0·2035	4·9152	0·9799	30	
	40	0·0116	0·0116	85·9398	0·9999	20			40	0·2022	0·2065	4·8430	0·9793	20	
	50	0·0145	0·0145	68·7501	0·9999	10			50	0·2051	0·2095	4·7729	0·9787	10	
1	0	0·0175	0·0175	57·2900	0·9998	0	89	12	0	0·2079	0·2126	4·7046	0·9781	0	78
	10	0·0204	0·0204	49·1039	0·9998	50			10	0·2108	0·2156	4·6382	0·9775	50	
	20	0·0233	0·0233	42·9641	0·9997	40			20	0·2136	0·2186	4·5736	0·9769	40	
	30	0·0262	0·0262	38·1885	0:9997	30			30	0·2164	0·2217	4·5107	0·9763	30	
	40	0·0291	0·0291	34·3678	0·9996	20			40	0·2193	0·2247	4·4494	0·9757	20	
	50	0·0320	0·0320	31·2416	0·9995	10			50	0·2221	0·2278	4·3897	0·9750	10	
2	0	0·0349	0·0349	28·6363	0·9994	0	88	13	0	0·2250	0·2309	4·3315	0·9744	0	77
	10	0·0378	0·0378	26·4316	0·9993	50			10	0·2278	0·2339	4·2747	0·9737	50	
	20	0·0407	0·0407	24·5418	0·9992	40			20	0·2306	0·2370	4·2193	0·9730	40	
	30	0·0436	0·0437	22·9038	0·9990	30			30	0·2334	0·2401	4·1653	0·9724	30	
	40	0·0465	0·0466	21·4704	0·9989	20			40	0·2363	0·2432	4·1126	0·9717	20	
	50	0·0494	0·0495	20·2056	0·9988	10			50	0·2391	0·2462	4·0611	0·9710	10	
3	0	0·0523	0·0524	19·0811	0·9986	0	87	14	0	0·2419	0·2493	4·0108	0·9703	0	76
	10	0·0552	0·0553	18·0750	0·9985	50			10	0·2447	0·2524	3·9617	0·9696	50	
	20	0·0581	0·0582	17·1693	0·9983	40			20	0·2476	0:2555	3·9136	0·9689	40	
	30	0·0610	0·0612	16·3499	0·9981	30			30	0·2504	0·2586	3·8667	0·9681	30	
	40	0·0640	0·0641	15·6048	0·9980	20			40	0·2532	0·2617	3·8208	0·9674	20	
	50	0·0669	0·0670	14·9244	0·9978	10			50	0·2560	0·2648	3·7760	0·9667	10	
4	0	0·0698	0·0699	14·3007	0·9976	0	86	15	0	0·2588	0·2679	3·7321	0·9659	0	75
	10	0·0727	0·0729	13·7267	0·9974	50			10	0·2616	0·2711	3·6891	0·9652	50	
	20	0·0756	0·0758	13·1969	0·9971	40			20	0·2644	0·2742	3·6470	0·9644	40	
	30	0·0785	0·0787	12·7062	0·9969	30			30	0·2672	0·2773	3·6059	0·9636	30	
	40	0·0814	0·0816	12·2505	0·9967	20			40	0·2700	0·2805	3·5656	0·9628	20	
	50	0·0843	0·0846	11·8262	0·9964	10			50	0·2728	0·2836	3·5261	0·9621	10	
5	0	0·0872	0·0875	11·4301	0·9962	0	85	16	0	0·2756	0·2867	3·4874	0·9613	0	74
	10	0·0901	0·0904	11·0594	0·9959	50			10	0·2784	0·2899	3·4495	0·9605	50	
	20	0·0929	0·0934	10·7119	0·9957	40			20	0·2812	0·2931	3·4124	0·9596	40	
	30	0·0958	0·0963	10·3854	0·9954	30			30	0·2840	0·2962	3·3759	0·9588	30	
	40	0·0987	0·0992	10·0780	0·9951	20			40	0·2868	0·2994	3·3402	0·9580	20	
	50	0·1016	0·1022	9·7882	0·9948	10			50	0·2896	0·3026	3·3052	0·9572	10	
6	0	0·1045	0·1051	9·5144	0·9945	0	84	17	0	0·2924	0·3057	3·2709	0·9563	0	73
	10	0·1074	0·1080	9·2553	0·9942	50			10	0·2952	0·3089	3·2371	0·9555	50	
	20	0·1103	0·1110	9·0098	0·9939	40			20	0·2979	0·3121	3·2041	0·9546	40	
	30	0·1132	0·1139	8·7769	0·9936	30			30	0·3007	0·3153	3·1716	0·9537	30	
	40	0·1161	0·1169	8·5555	0·9932	20			40	0·3035	0·3185	3·1397	0·9528	20	
	50	0·1190	0·1198	8·3450	0·9929	10			50	0·3062	0·3217	3·1084	0·9520	10	
7	0	0·1219	0·1228	8·1443	0·9925	0	83	18	0	0·3090	0·3249	3·0777	0·9511	0	72
	10	0·1248	0·1257	7·9530	0·9922	50			10	0·3118	0·3281	3·0475	0·9502	50	
	20	0·1276	0·1287	7·7704	0·9918	40			20	0·3145	0·3314	3·0178	0·9492	40	
	30	0·1305	0·1317	7·5958	0·9914	30			30	0·3173	0·3346	2·9887	0·9483	30	
	40	0·1334	0·1346	7·4287	0·9911	20			40	0·3201	0·3378	2·9600	0·9474	20	
	50	0·1363	0·1376	7·2687	0·9907	10			50	0·3228	0·3411	2·9319	0·9465	10	
8	0	0·1392	0·1405	7·1154	0·9903	0	82	19	0	0·3256	0·3443	2·9042	0·9455	0	71
	10	0·1421	0·1435	6·9682	0·9899	50			10	0·3283	0·3476	2·8770	0·9446	50	
	20	0·1449	0·1465	6·8269	0·9894	40			20	0·3311	0·3508	2·8502	0·9436	40	
	30	0·1478	0·1495	6·6912	0·9890	30			30	0·3338	0·3541	2·8239	0·9426	30	
	40	0·1507	0·1524	6·5606	0·9886	20			40	0·3365	0·3574	2·7980	0·9417	20	
	50	0·1536	0·1554	6·4348	0·9881	10			50	0·3393	0·3607	2·7725	0·9407	10	
9	0	0·1564	0·1584	6·3138	0·9877	0	81	20	0	0·3420	0·3640	2·7475	0·9397	0	70
	10	0·1593	0·1614	6·1970	0·9872	50			10	0·3448	0·3673	2·7228	0·9387	50	
	20	0·1622	0·1644	6·0844	0·9868	40			20	0·3475	0·3706	2·6985	0·9377	40	
	30	0·1650	0·1673	5·9758	0·9863	30			30	0·3502	0·3739	2·6746	0·9367	30	
	40	0·1679	0·1703	5·8708	0·9858	20			40	0·3529	0·3772	2·6511	0·9356	20	
	50	0·1708	0·1733	5·7694	0·9853	10			50	0·3557	0·3805	2·6279	0·9346	10	
10	0	0·1736	0·1763	5·6713	0·9848	0	80	21	0	0·3584	0·3839	2·6051	0·9336	0	69
	10	0·1765	0·1793	5·5764	0·9843	50			10	0·3611	0·3872	2·5826	0·9325	50	
	20	0·1794	0·1823	5·4845	0·9838	40			20	0·3638	0·3906	2·5605	0·9315	40	
	30	0·1822	0·1853	5·3955	0·9833	30			30	0·3665	0·3939	2·5386	0·9304	30	
	40	0·1851	0·1883	5·3093	0·9827	20			40	0·3692	0·3973	2·5172	0·9293	20	
	50	0·1880	0·1914	5·2257	0·9822	10			50	0·3719	0·4006	2·4960	0·9283	10	
°	′	Cosine	Cotan.	Tan.	Sine	′	°	°	′	Cosine	Cotan.	Tan.	Sine	′	

NATURAL SINES, TANGENTS, COTANGENTS AND COSINES

To Ten Minutes of Arc —*continued*

°	′	Sine	Tan.	Cotan.	Cosine	′	°
22	0	0·3746	0·4040	2·4751	0·9272	0	68
	10	0·3773	0·4074	2·4545	0·9261	50	
	20	0·3800	0·4108	2·4342	0·9250	40	
	30	0·3827	0·4142	2·4142	0·9239	30	
	40	0·3854	0·4176	2·3945	0·9228	20	
	50	0·3881	0·4210	2·3750	0·9216	10	
23	0	0·3907	0·4245	2·3559	0·9205	0	67
	10	0·3934	0·4279	2·3369	0·9194	50	
	20	0·3961	0·4314	2·3183	0·9182	40	
	30	0·3987	0·4348	2·2998	0·9171	30	
	40	0·4014	0·4383	2·2817	0·9159	20	
	50	0·4041	0·4417	2·2637	0·9147	10	
24	0	0·4067	0·4452	2·2460	0·9135	0	66
	10	0·4094	0·4487	2·2286	0·9124	50	
	20	0·4120	0·4522	2·2113	0·9112	40	
	30	0·4147	0·4557	2·1943	0·9100	30	
	40	0·4173	0·4592	2·1775	0·9088	20	
	50	0·4200	0·4628	2·1609	0·9075	10	
25	0	0·4226	0·4663	2·1445	0·9063	0	65
	10	0·4253	0·4699	2·1283	0·9051	50	
	20	0·4279	0·4734	2·1123	0·9038	40	
	30	0·4305	0·4770	2·0965	0·9026	30	
	40	0·4331	0·4806	2·0809	0·9013	20	
	50	0·4358	0·4841	2·0655	0·9001	10	
26	0	0·4384	0·4877	2·0503	0·8988	0	64
	10	0·4410	0·4913	2·0353	0·8975	50	
	20	0·4436	0·4950	2·0204	0·8962	40	
	30	0·4462	0·4986	2·0057	0·8949	30	
	40	0·4488	0·5022	1·9912	0·8936	20	
	50	0·4514	0·5059	1·9768	0·8923	10	
27	0	0·4540	0·5095	1·9626	0·8910	0	63
	10	0·4566	0·5132	1·9486	0·8897	50	
	20	0·4592	0·6169	1·9347	0·8884	40	
	30	0·4617	0·5206	1·9210	0·8870	30	
	40	0·4643	0·5243	1·9074	0·8857	20	
	50	0·4669	0·5280	1·8940	0·8843	10	
28	0	0·4695	0·5317	1·8807	0·8829	0	62
	10	0·4720	0·5354	1·8676	0·8816	50	
	20	0·4746	0·5392	1·8546	0·8802	40	
	30	0·4772	0·5430	1·8418	0·8788	30	
	40	0·4797	0·5467	1·8291	0·8774	20	
	50	0·4823	0·5505	1·8165	0·8760	10	
29	0	0·4848	0·5543	1·8040	0·8746	0	61
	10	0·4874	0·5581	1·7917	0·8732	50	
	20	0·4899	0·5619	1·7796	0·8718	40	
	30	0·4924	0·5658	1·7675	0·8704	30	
	40	0·4950	0·5696	1·7556	0·8689	20	
	50	0·4974	0·5735	1·7437	0·8675	10	
30	0	0·5000	0·5774	1·7321	0·8660	0	60
	10	0·5025	0·5812	1·7205	0·8646	50	
	20	0·5050	0·5851	1·7090	0·8631	40	
	30	0·5075	0·5890	1·6977	0·8616	30	
	40	0·5100	0·5930	1·6864	0·8601	20	
	50	0·5125	0·5969	1·6753	0·8587	10	
31	0	0·5150	0·6009	1·6643	0·8572	0	59
	10	0·5175	0·6048	1·6534	0·8557	50	
	20	0·5200	0·6088	1·6426	0·8542	40	
	30	0·5225	0·6128	1·6319	0·8526	30	
	40	0·5250	0·6168	1·6212	0·8511	20	
	50	0·5275	0·6208	1·6107	0·8496	10	
32	0	0·5299	0·6249	1·6003	0·8480	0	58
	10	0·5324	0·6289	1·5900	0·8465	50	
	20	0·5348	0·6330	1·5798	0·8450	40	
	30	0·5373	0·6371	1·5697	0·8434	30	
	40	0·5398	0·6412	1·5597	0·8418	20	
	50	0·5422	0·6453	1·5497	0·8403	10	
33	0	0·5446	0·6494	1·5399	0·8387	0	57
	10	0·5471	0·6536	1·5301	0·8371	50	
	20	0·5495	0·6577	1·5204	0·8355	40	
°	′	Cosine	Cotan.	Tan.	Sine	′	°

°	′	Sine	Tan.	Cotan.	Cosine	′	°
	30	0·5519	0·6619	1·5108	0·8339	30	
	40	0·5544	0·6661	1·5013	0·8323	20	
	50	0·5568	0·6703	1·4919	0·8307	10	
34	0	0·5592	0·6745	1·4826	0·8290	0	56
	10	0·5616	0·6787	1·4733	0·8274	50	
	20	0·5640	0·6830	1·4641	0·8258	40	
	30	0·5664	0·6873	1·4550	0·8241	30	
	40	0·5688	0·6916	1·4460	0·8225	20	
	50	0·5712	0·6959	1·4370	0·8208	10	
35	0	0·5736	0·7002	1·4281	0·8192	0	55
	10	0·5760	0·7046	1·4193	0·8175	50	
	20	0·5783	0·7089	1·4106	0·8158	40	
	30	0·5807	0·7133	1·4019	0·8141	30	
	40	0·5831	0·7177	1·3934	0·8124	20	
	50	0·5854	0·7221	1·3848	0·8107	10	
36	0	0·5878	0·7265	1·3764	0·8090	0	54
	10	0·5901	0·7310	1·3680	0·8073	50	
	20	0·5925	0·7355	1·3597	0·8056	40	
	30	0·5948	0·7400	1·3514	0·8039	30	
	40	0·5972	0·7445	1·3432	0·8021	20	
	50	0·5995	0·7490	1·3351	0·8004	10	
37	0	0·6018	0·7536	1·3270	0·7986	0	53
	10	0·6041	0·7581	1·3190	0·7969	50	
	20	0·6065	0·7627	1·3111	0·7951	40	
	30	0·6088	0·7673	1·3032	0·7934	30	
	40	0·6111	0·7720	1·2954	0·7916	20	
	50	0·6134	0·7766	1·2876	0·7898	10	
38	0	0·6157	0·7813	1·2799	0·7880	0	52
	10	0·6180	0·7860	1·2723	0·7862	50	
	20	0·6202	0·7907	1·2647	0·7844	40	
	30	0·6225	0·7954	1·2572	0·7826	30	
	40	0·6248	0·8002	1·2497	0·7808	20	
	50	0·6271	0·8050	1·2423	0·7790	10	
39	0	0·6293	0·8098	1·2349	0·7771	0	51
	10	0·6316	0·8146	1·2276	0·7753	50	
	20	0·6338	0·8195	1·2203	0·7735	40	
	30	0·6361	0·8243	1·2131	0·7716	30	
	40	0·6383	0·8292	1·2059	0·7698	20	
	50	0·6406	0·8342	1·1988	0·7679	10	
40	0	0·6428	0·8391	1·1918	0·7660	0	50
	10	0·6450	0·8441	1·1847	0·7642	50	
	20	0·6472	0·8491	1·1778	0·7623	40	
	30	0·6494	0·8541	1·1708	0·7604	30	
	40	0·6517	0·8591	1·1640	0·7585	20	
	50	0·6539	0·8642	1·1571	0·7566	10	
41	0	0·6561	0·8693	1·1504	0·7547	0	49
	10	0·6583	0·8744	1·1436	0·7528	50	
	20	0·6604	0·8796	1·1369	0·7509	40	
	30	0·6626	0·8847	1·1303	0·7490	30	
	40	0·6648	0·8899	1·1237	0·7470	20	
	50	0·6670	0·8952	1·1171	0·7451	10	
42	0	0·6691	0·9004	1·1106	0·7431	0	48
	10	0·6713	0·9057	1·1041	0·7412	50	
	20	0·6734	0·9110	1·0977	0·7392	40	
	30	0·6756	0·9163	1·0913	0·7373	30	
	40	0·6777	0·9217	1·0850	0·7353	20	
	50	0·6799	0·9271	1·0786	0·7333	10	
43	0	0·6820	0·9325	1·0724	0·7314	0	47
	10	0·6841	0·9380	1·0661	0·7294	50	
	20	0·6862	0·9435	1·0599	0·7274	40	
	30	0·6884	0·9490	1·0538	0·7254	30	
	40	0·6905	0·9545	1·0477	0·7234	20	
	50	0·6926	0·9601	1·0416	0·7214	10	
44	0	0·6947	0·9657	1·0355	0·7193	0	46
	10	0·6967	0·9713	1·0295	0·7173	50	
	20	0·6988	0·9770	1·0235	0·7153	40	
	30	0·7009	0·9827	1·0176	0·7133	30	
	40	0·7030	0·9884	1·0117	0·7112	20	
	50	0·7050	0·9942	1·0058	0·7092	10	
45	0	0·7071	1·0000	1·0000	0·7071	0	45
°	′	Cosine	Cotan.	Tan.	Sine	′	°

DEGREES OF RADIANS

Degrees	0′ 0°·0	6′ 0°·1	12′ 0°·2	18′ 0°·3	24′ 0°·4	30′ 0°·5	36′ 0°·6	42′ 0°·7	48′ 0°·8	54′ 0°·9	Mean Differences 1	2	3	4	5
0	0·0000	0017	0035	0052	0070	0087	0105	0122	0140	0157	3	6	9	12	15
1	0·0175	0192	0209	0227	0244	0262	0279	0297	0314	0332	3	6	9	12	15
2	0·0349	0367	0384	0401	0419	0436	0454	0471	0489	0506	3	6	9	12	15
3	0·0524	0541	0559	0576	0593	0611	0628	0646	0663	0681	3	6	9	12	15
4	0·0698	0716	0733	0750	0768	0785	0803	0820	0838	0855	3	6	9	12	15
5	0·0873	0890	0908	0925	0942	0960	0977	0995	1012	1030	3	6	9	12	15
6	0·1047	1065	1082	1100	1117	1134	1152	1169	1187	1204	3	6	9	12	15
7	0·1222	1239	1257	1274	1292	1309	1326	1344	1361	1379	3	6	9	12	15
8	0·1396	1414	1431	1449	1466	1484	1501	1518	1536	1553	3	6	9	12	15
9	0·1571	1588	1606	1623	1641	1658	1676	1693	1710	1728	3	6	9	12	15
10	0·1745	1763	1780	1798	1815	1833	1850	1868	1885	1902	3	6	9	12	15
11	0·1920	1937	1955	1972	1990	2007	2025	2042	2060	2077	3	6	9	12	15
12	0·2094	2112	2129	2147	2164	2182	2199	2217	2234	2251	3	6	9	12	15
13	0·2269	2286	2304	2321	2339	2356	2374	2391	2409	2426	3	6	9	12	15
14	0·2443	2461	2478	2496	2513	2531	2548	2566	2583	2601	3	6	9	12	15
15	0·2618	2635	2653	2670	2688	2705	2723	2740	2758	2775	3	6	9	12	15
16	0·2793	2810	2827	2845	2862	2880	2897	2915	2932	2950	3	6	9	12	15
17	0·2967	2985	3002	3019	3037	3054	3072	3089	3107	3124	3	6	9	12	15
18	0·3142	3159	3176	3194	3211	3229	3246	3264	3281	3299	3	6	9	12	15
19	0·3316	3334	3351	3368	3386	3403	3421	3438	3456	3473	3	6	9	12	15
20	0·3491	3508	3526	3543	3560	3578	3595	3613	3630	3648	3	6	9	12	15
21	0·3665	3683	3700	3718	3735	3752	3770	3787	3805	3822	3	6	9	12	15
22	0·3840	3857	3875	3892	3910	3927	3944	3962	3979	3997	3	6	9	12	15
23	0·4014	4032	4049	4067	4084	4102	4119	4136	4154	4171	3	6	9	12	15
24	0·4189	4206	4224	4241	4259	4276	4294	4311	4328	4346	3	6	9	12	15
25	0·4363	4381	4398	4416	4433	4451	4468	4485	4503	4520	3	6	9	12	15
26	0·4538	4555	4573	4590	4608	4625	4643	4660	4677	4695	3	6	9	12	15
27	0·4712	4730	4747	4765	4782	4800	4817	4835	4852	4869	3	6	9	12	15
28	0·4887	4904	4922	4939	4957	4974	4992	5009	5027	5044	3	6	9	12	15
29	0·5061	5079	5096	5114	5131	5149	5166	5184	5201	5219	3	6	9	12	15
30	0·5236	5253	5271	5288	5306	5323	5341	5358	5376	5393	3	6	9	12	15
31	0·5411	5428	5445	5463	5480	5498	5515	5533	5550	5568	3	6	9	12	15
32	0·5585	5603	5620	5637	5655	5672	5690	5707	5725	5742	3	6	9	12	15
33	0·5760	5777	5794	5812	5829	5847	5864	5882	5899	5917	3	6	9	12	15
34	0·5934	5952	5969	5986	6004	6021	6039	6056	6074	6091	3	6	9	12	15
35	0·6109	6126	6144	6161	6178	6196	6213	6231	6248	6266	3	6	9	12	15
36	0·6283	6301	6318	6336	6353	6370	6388	6405	6423	6440	3	6	9	12	15
37	0·6458	6475	6493	6510	6528	6545	6562	6580	6597	6615	3	6	9	12	15
38	0·6632	6650	6667	6685	6702	6720	6737	6754	6772	6789	3	6	9	12	15
39	0·6807	6824	6842	6859	6877	6894	6912	6929	6946	6964	3	6	9	12	15
40	0·6981	6999	7016	7034	7051	7069	7086	7103	7121	7138	3	6	9	12	15
41	0·7156	7173	7191	7208	7226	7243	7261	7278	7295	7313	3	6	9	12	15
42	0·7330	7348	7365	7383	7400	7418	7435	7453	7470	7487	3	6	9	12	15
43	0·7505	7522	7540	7557	7575	7592	7610	7627	7645	7662	3	6	9	12	15
44	0·7679	7697	7714	7732	7749	7767	7784	7802	7819	7837	3	6	9	12	15

DEGREES OF RADIANS—*continued*

Degrees	0′ 0°·0	6′ 0°·1	12′ 0°·2	18′ 0°·3	24′ 0°·4	30′ 0°·5	36′ 0°·6	42′ 0°·7	48′ 0°·8	54′ 0°·9	Mean Differences 1	2	3	4	5
45	0·7854	7871	7889	7906	7924	7941	7959	7976	7994	8011	3	6	9	12	15
46	0·8029	8046	8063	8081	8098	8116	8133	8151	8168	8186	3	6	9	12	15
47	0·8203	8221	8238	8255	8273	8290	8308	8325	8343	8360	3	6	9	12	15
48	0·8378	8395	8412	8430	8447	8465	8482	8500	8517	8535	3	6	9	12	15
49	0·8552	8570	8587	8604	8622	8639	8657	8674	8692	8709	3	6	9	12	15
50	0·8727	8744	8762	8779	8796	8814	8831	8849	8866	8884	3	6	9	12	15
51	0·8901	8919	8936	8954	8971	8988	9006	9023	9041	9058	3	6	9	12	15
52	0·9076	9093	9111	9128	9146	9163	9180	9198	9215	9233	3	6	9	12	15
53	0·9250	9268	9285	9303	9320	9338	9355	9372	9390	9407	3	6	9	12	15
54	0·9425	9442	9460	9477	9495	9512	9529	9547	9564	9582	3	6	9	12	15
55	0·9599	9617	9634	9652	9669	9687	9704	9721	9739	9756	3	6	9	12	15
56	0·9774	9791	9809	9826	9844	9861	9879	9896	9913	9931	3	6	9	12	15
57	0·9948	9966	9983	1·0001	1·0018	1·0036	1·0053	1·0071	1·0088	1·0105	3	6	9	12	15
58	1·0123	0140	0158	0175	0193	0210	0228	0245	0263	0280	3	6	9	12	15
59	1·0297	0315	0332	0350	0367	0385	0402	0420	0437	0455	3	6	9	12	15
60	1·0472	0489	0507	0524	0542	0559	0577	0594	0612	0629	3	6	9	12	15
61	1·0647	0664	0681	0699	0716	0734	0751	0769	0786	0804	3	6	9	12	15
62	1·0821	0838	0856	0873	0891	0908	0926	0943	0961	0978	3	6	9	12	15
63	1·0996	1013	1030	1048	1065	1083	1100	1118	1135	1153	3	6	9	12	15
64	1·1170	1188	1205	1222	1240	1257	1275	1292	1310	1327	3	6	9	12	15
65	1·1345	1362	1380	1397	1414	1432	1449	1467	1484	1502	3	6	9	12	15
66	1·1519	1537	1554	1572	1589	1606	1624	1641	1659	1676	3	6	9	12	15
67	1·1694	1711	1729	1746	1764	1781	1798	1816	1833	1851	3	6	9	12	15
68	1·1868	1886	1903	1921	1938	1956	1973	1990	2008	2025	3	6	9	12	15
69	1·2043	2060	2078	2095	2113	2130	2147	2165	2182	2200	3	6	9	12	15
70	1·2217	2235	2252	2270	2287	2305	2322	2339	2357	2374	3	6	9	12	15
71	1·2392	2409	2427	2444	2462	2479	2497	2514	2531	2549	3	6	9	12	15
72	1·2566	2584	2601	2619	2636	2654	2671	2689	2706	2723	3	6	9	12	15
73	1·2741	2758	2776	2793	2811	2828	2846	2863	2881	2898	3	6	9	12	15
74	1·2915	2933	2950	2968	2985	3003	3020	3038	3055	3073	3	6	9	12	15
75	1·3090	3107	3125	3142	3160	3177	3195	3212	3230	3247	3	6	9	12	15
76	1·3265	3282	3299	3317	3334	3352	3369	3387	3404	3422	3	6	9	12	15
77	1·3439	3456	3474	3491	3509	3526	3544	3561	3579	3596	3	6	9	12	15
78	1·3614	3631	3648	3666	3683	3701	3718	3736	3753	3771	3	6	9	12	15
79	1·3788	3806	3823	3840	3858	3875	3893	3910	3928	3945	3	6	9	12	15
80	1·3963	3980	3998	4015	4032	4050	4067	4085	4102	4120	3	6	9	12	15
81	1·4137	4155	4172	4190	4207	4224	4242	4259	4277	4294	3	6	9	12	15
82	1·4312	4329	4347	4364	4382	4399	4416	4434	4451	4469	3	6	9	12	15
83	1·4486	4504	4521	4539	4556	4573	4591	4608	4626	4643	3	6	9	12	15
84	1·4661	4678	4696	4713	4731	4748	4765	4783	4800	4818	3	6	9	12	15
85	1·4835	4853	4870	4888	4905	4923	4940	4957	4975	4992	3	6	9	12	15
86	1·5010	5027	5045	5062	5080	5097	5115	5132	5149	5167	3	6	9	12	15
87	1·5184	5202	5219	5237	5254	5272	5289	5307	5324	5341	3	6	9	12	15
88	1·5359	5376	5394	5411	5429	5446	5464	5481	5499	5516	3	6	9	12	15
89	1·5533	5551	5568	5586	5603	5621	5638	5656	5673	5691	3	6	9	12	15

SQUARE ROOTS. From 1 to 10

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
1·0	1·000	1·005	1·010	1·015	1·020	1·025	1·030	1·034	1·039	1·044	0	1	1	2	2	3	3	4	4
1·1	1·049	1·054	1·058	1·063	1·068	1·072	1·077	1·082	1·086	1·091	0	1	1	2	2	3	3	4	4
1·2	1·095	1·100	1·105	1·109	1·114	1·118	1·122	1·127	1·131	1·136	0	1	1	2	2	3	3	4	4
1·3	1·140	1·145	1·149	1·153	1·158	1·162	1·166	1·170	1·175	1·179	0	1	1	2	2	3	3	3	4
1·4	1·183	1·187	1·192	1·196	1·200	1·204	1·208	1·212	1·217	1·221	0	1	1	2	2	2	3	3	4
1·5	1·225	1·229	1·233	1·237	1·241	1·245	1·249	1·253	1·257	1·261	0	1	1	2	2	2	3	3	4
1·6	1·265	1·269	1·273	1·277	1·281	1·285	1·288	1·292	1·296	1·300	0	1	1	2	2	2	3	3	3
1·7	1·304	1·308	1·311	1·315	1·319	1·323	1·327	1·330	1·334	1·338	0	1	1	2	2	2	3	3	3
1·8	1·342	1·345	1·349	1·353	1·356	1·360	1·364	1·367	1·371	1·375	0	1	1	1	2	2	3	3	3
1·9	1·378	1·382	1·386	1·389	1·393	1·396	1·400	1·404	1·407	1·411	0	1	1	1	2	2	3	3	3
2·0	1·414	1·418	1·421	1·425	1·428	1·432	1·435	1·439	1·442	1·446	0	1	1	1	2	2	2	3	3
2·1	1·449	1·453	1·456	1·459	1·463	1·466	1·470	1·473	1·476	1·480	0	1	1	1	2	2	2	3	3
2·2	1·483	1·487	1·490	1·493	1·497	1·500	1·503	1·507	1·510	1·513	0	1	1	1	2	2	2	3	3
2·3	1·517	1·520	1·523	1·526	1·530	1·533	1·536	1·539	1·543	1·546	0	1	1	1	2	2	2	3	3
2·4	1·549	1·552	1·556	1·559	1·562	1·565	1·568	1·572	1·575	1·578	0	1	1	1	2	2	2	3	3
2·5	1·581	1·584	1·587	1·591	1·594	1·597	1·600	1·603	1·606	1·609	0	1	1	1	2	2	2	3	3
2·6	1·612	1·616	1·619	1·622	1·625	1·628	1·631	1·634	1·637	1·640	0	1	1	1	2	2	2	2	3
2·7	1·643	1·646	1·649	1·652	1·655	1·658	1·661	1·664	1·667	1·670	0	1	1	1	2	2	2	2	3
2·8	1·673	1·676	1·679	1·682	1·685	1·688	1·691	1·694	1·697	1·700	0	1	1	1	1	2	2	2	3
2·9	1·703	1·706	1·709	1·712	1·715	1·718	1·720	1·723	1·726	1·729	0	1	1	1	1	2	2	2	3
3·0	1·732	1·735	1·738	1·741	1·744	1·746	1·749	1·752	1·755	1·758	0	1	1	1	1	2	2	2	3
3·1	1·761	1·764	1·766	1·769	1·772	1·775	1·778	1·780	1·783	1·786	0	1	1	1	1	2	2	2	3
3·2	1·789	1·792	1·794	1·797	1·800	1·803	1·806	1·808	1·811	1·814	0	1	1	1	1	2	2	2	2
3·3	1·817	1·819	1·822	1·825	1·828	1·830	1·833	1·836	1·838	1·841	0	1	1	1	1	2	2	2	2
3·4	1·844	1·847	1·849	1·852	1·855	1·857	1·860	1·863	1·865	1·868	0	1	1	1	1	2	2	2	2
3·5	1·871	1·873	1·376	1·879	1·881	1·884	1·887	1·889	1·892	1·895	0	1	1	1	1	2	2	2	2
3·6	1·897	1·900	1·903	1·905	1·908	1·910	1·913	1·916	1·918	1·921	0	1	1	1	1	2	2	2	2
3·7	1·924	1·926	1·929	1·931	1·934	1·936	1·939	1·942	1·944	1·947	0	1	1	1	1	2	2	2	2
3·8	1·949	1·952	1·954	1·957	1·960	1·962	1·965	1·967	1·970	1·972	0	1	1	1	1	2	2	2	2
3·9	1·975	1·977	1·980	1·982	1·985	1·987	1·990	1·992	1·995	1·997	0	1	1	1	1	2	2	2	2
4·0	2·000	2·002	2·005	2·007	2·010	2·012	2·015	2·017	2·020	2·022	0	0	1	1	1	1	2	2	2
4·1	2·025	2·027	2·030	2·032	2·035	2·037	2·040	2·042	2·045	2·047	0	0	1	1	1	1	2	2	2
4·2	2·049	2·052	2·054	2·057	2·059	2·062	2·064	2·066	2·069	2·071	0	0	1	1	1	1	2	2	2
4·3	2·074	2·076	2·078	2·081	2·083	2·086	2·088	2·090	2·093	2·095	0	0	1	1	1	1	2	2	2
4·4	2·098	2·100	2·102	2·105	2·107	2·110	2·112	2·114	2·117	2·119	0	0	1	1	1	1	2	2	2
4·5	2·121	2·124	2·126	2·128	2·131	2·133	2·135	2·138	2·140	2·142	0	0	1	1	1	1	2	2	2
4·6	2·145	2·147	2·149	2·152	2·154	2·156	2·159	2·161	2·163	2·166	0	0	1	1	1	1	2	2	2
4·7	2·168	2·170	2·173	2·175	2·177	2·179	2·182	2·184	2·186	2·189	0	0	1	1	1	1	2	2	2
4·8	2·191	2·193	1·195	2·198	2·200	2·202	2·205	2·207	2·209	2·211	0	0	1	1	1	1	2	2	2
4·9	2·214	2·216	2·218	2·220	2·223	2·225	2·227	2·229	2·232	2·234	0	0	1	1	1	1	2	2	2
5·0	2·236	2·238	2·241	2·243	2·245	2·247	2·249	2·252	2·254	2·256	0	0	1	1	1	1	2	2	2
5·1	2·258	2·261	2·263	2·265	2·267	2·269	2·272	2·274	2·276	2·278	0	0	1	1	1	1	2	2	2
5·2	2·280	2·283	2·285	2·287	2·289	2·291	2·293	2·296	2·298	2·300	0	0	1	1	1	1	2	2	2
5·3	2·302	2·304	2·307	2·309	2·311	2·313	2·315	2·317	2·319	2·322	0	0	1	1	1	1	2	2	2
5·4	2·324	2·326	2·328	2·330	2·332	2·335	2·337	2·339	2·341	2·343	0	0	1	1	1	1	1	2	2

SQUARE ROOTS. From 1 to 10—*continued*

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
5·5	2·345	2·347	2·349	2·352	2·354	2·356	2·358	2·360	2·362	2·364	0	0	1	1	1	1	1	2	2
5·6	2·366	2·369	2·371	2·373	2·375	2·377	2·379	2·381	2·383	2·385	0	0	1	1	1	1	1	2	2
5·7	2·387	2·390	2·392	2·394	2·396	2·398	2·400	2·402	2·404	2·406	0	0	1	1	1	1	1	2	2
5·8	2·408	2·410	2·412	2·415	2·417	2·419	2·421	2·423	2·425	2·427	0	0	1	1	1	1	1	2	2
5·9	2·429	2·431	2·433	2·435	2·437	2·439	2·441	2·443	2·445	2·447	0	0	1	1	1	1	1	2	2
6·0	2·449	2·452	2·454	2·456	2·458	2·460	2·462	2·464	2·466	2·468	0	0	1	1	1	1	1	2	2
6·1	2·470	2·472	2·474	2·476	2·478	2·480	2·482	2·484	2·486	2·488	0	0	1	1	1	1	1	2	2
6·2	2·490	2·492	2·494	2·496	2·498	2·500	2·502	2·504	2·506	2·508	0	0	1	1	1	1	1	2	2
6·3	2·510	2·512	2·514	2·516	2·518	2·520	2·522	2·524	2·526	2·528	0	0	1	1	1	1	1	2	2
6·4	2·530	2·532	2·534	2·536	2·538	2·540	2·542	2·544	2·546	2·548	0	0	1	1	1	1	1	2	2
6·5	2·550	2·551	2·553	2·555	2·557	2·559	2·561	2·563	2·565	2·567	0	0	1	1	1	1	1	2	2
6·6	2·569	2·571	2·573	2·575	2·577	2·579	2·581	2·583	2·585	2·587	0	0	1	1	1	1	1	2	2
6·7	2·588	2·590	2·592	2·594	2·596	2·598	2·600	2·602	2·604	2·606	0	0	1	1	1	1	1	2	2
6·8	2·608	2·610	2·612	2·613	2·615	2·617	2·619	2·621	2·623	2·625	0	0	1	1	1	1	1	2	2
6·9	2·627	2·629	2·631	2·632	2·634	2·636	2·638	2·640	2·642	2·644	0	0	1	1	1	1	1	2	2
7·0	2·646	2·648	2·650	2·651	2·653	2·655	2·657	2·659	2·661	2·663	0	0	1	1	1	1	1	2	2
7·1	2·665	2·666	2·668	2·670	2·672	2·674	2·676	2·678	2·680	2·681	0	0	1	1	1	1	1	1	2
7·2	2·683	2·685	2·687	2·689	2·691	2·693	2·694	2·696	2·698	2·700	0	0	1	1	1	1	1	1	2
7·3	2·702	2·704	2·706	2·707	2·709	2·711	2·713	2·715	2·717	2·718	0	0	1	1	1	1	1	1	2
7·4	2·720	2·722	2·724	2·726	2·728	2·729	2·731	2·733	2·735	2·737	0	0	1	1	1	1	1	1	2
7·5	2·739	2·740	2·742	2·744	2·746	2·748	2·750	2·751	2·753	2·755	0	0	1	1	1	1	1	1	2
7·6	2·757	2·759	2·760	2·762	2·764	2·766	2·768	2·769	2·771	2·773	0	0	1	1	1	1	1	1	2
7·7	2·775	2·777	2·778	2·780	2·782	2·784	2·786	2·787	2·789	2·791	0	0	1	1	1	1	1	1	2
7·8	2·793	2·795	2·796	2·798	2·800	2·802	2·804	2·805	2·807	2·809	0	0	1	1	1	1	1	1	2
7·9	2·811	2·812	2·814	2·816	2·818	2·820	2·821	2·823	2·825	2·827	0	0	1	1	1	1	1	1	2
8·0	2·828	2·830	2·832	2·834	2·835	2·837	2·839	2·841	2·843	2·844	0	0	1	1	1	1	1	1	2
8·1	2·846	2·848	2·850	2·851	2·853	2·855	2·857	2·858	2·860	2·862	0	0	1	1	1	1	1	1	2
8·2	2·864	2·865	2·867	2·869	2·871	2·872	2·874	2·876	2·877	2·879	0	0	1	1	1	1	1	1	2
8·3	2·881	2·883	2·884	2·886	2·888	2·890	2·891	2·893	2·895	2·897	0	0	1	1	1	1	1	1	2
8·4	2·898	2·900	2·902	2·903	2·905	2·907	2·909	2·910	2·912	2·914	0	0	1	1	1	1	1	1	2
8·5	2·915	2·917	2·919	2·921	2·922	2·924	2·926	2·927	2·929	2·931	0	0	1	1	1	1	1	1	2
8·6	2·933	2·934	2·936	2·938	2·939	2·941	2·943	2·944	2·946	2·948	0	0	1	1	1	1	1	1	2
8·7	2·950	2·951	2·953	2·955	2·956	2·958	2·960	2·961	2·963	2·965	0	0	1	1	1	1	1	1	2
8·8	2·966	2·968	2·970	2·972	2·973	2·975	2·977	2·978	2·980	2·982	0	0	1	1	1	1	1	1	2
8·9	2·983	2·985	2·987	2·988	2·990	2·992	2·993	2·995	2·997	2·998	0	0	1	1	1	1	1	1	2
9·0	3·000	3·002	3·003	3·005	3·007	3·008	3·010	3·012	3·013	3·015	0	0	0	1	1	1	1	1	1
9·1	3·017	3·018	3·020	3·022	3·023	3·025	3·027	3·028	3·030	3·032	0	0	0	1	1	1	1	1	1
9·2	3·033	3·035	3·036	3·038	3·040	3·041	3·043	3·045	3·046	3·048	0	0	0	1	1	1	1	1	1
9·3	3·050	3·051	3·053	3·055	3·056	3·058	3·059	3·061	3·063	3·064	0	0	0	1	1	1	1	1	1
9·4	30·66	3·068	3·069	3·071	3·072	3·074	3·076	3·077	3·079	3·081	0	0	0	1	1	1	1	1	1
9·5	3·082	3·084	3·085	3·087	3·089	3·090	3·092	3·094	3·095	3·097	0	0	0	1	1	1	1	1	1
9·6	3·098	3·100	3·102	3·103	3·105	3·106	3·108	3·110	3·111	3·113	0	0	0	1	1	1	1	1	1
9·7	3·114	3·116	3·118	3·119	3·121	3·122	3·124	3·126	3·127	3·129	0	0	0	1	1	1	1	1	1
9·8	3·130	3·132	3·134	3·135	3·137	3·138	3·140	3·142	3·143	3·145	0	0	0	1	1	1	1	1	1
9·9	3·146	3·148	3·150	3·151	3·153	3·154	3·156	3·158	3·159	3·161	0	0	0	1	1	1	1	1	1

SQUARE ROOTS. From 10 to 100

	0	1	2	3	4	5	6	7	8	9	Mean Differences 1	2	3	4	5	6	7	8	9
10	3·162	3·178	3·194	3·209	3·225	3·240	3·256	3·271	3·286	3·302	2	3	5	6	8	9	11	12	14
11	3·317	3·332	3·347	3·362	3·376	3·391	3·406	3·421	3·435	3·450	1	3	4	6	7	9	10	12	13
12	3·464	3·479	3·493	3·507	3·521	3·536	3·550	3·564	3·578	3·592	1	3	4	6	7	8	10	11	13
13	3·606	3·619	3·633	3·647	3·661	3·674	3·688	3·701	3·715	3·728	1	3	4	5	7	8	10	11	12
14	3·742	3·755	3·768	3·782	3·795	3·808	3·821	3·834	3·847	3·860	1	3	4	5	7	8	9	11	12
15	3·873	3·886	3·899	3·912	3·924	3·937	3·950	3·962	3·975	3·987	1	3	4	5	6	8	9	10	11
16	4·000	4·012	4·025	4·037	4·050	4·062	4·074	4·087	4·099	4·111	1	2	4	5	6	7	9	10	11
17	4·123	4·135	4·147	4·159	4·171	4·183	4·195	4·207	4·219	4·231	1	2	4	5	6	7	8	10	11
18	4·243	4·254	4·266	4·278	4·290	4·301	4·313	4·324	4·336	4·347	1	2	3	5	6	7	8	9	10
19	4·359	4·370	4·382	4·393	4·405	4·416	4·427	4·438	4·450	4·461	1	2	3	5	6	7	8	9	10
20	4·472	4·483	4·494	4·506	4·517	4·528	4·539	4·550	4·561	4·572	1	2	3	4	6	7	8	9	10
21	4·583	4·593	4·604	4·615	4·626	4·637	4·648	4·658	4·669	4·680	1	2	3	4	5	6	8	9	10
22	4·690	4·701	4·712	4·722	4·733	4·743	4·754	4·764	4·775	4·785	1	2	3	4	5	6	7	8	9
23	4·796	4·806	4·817	4·827	4·837	4·848	4·858	4·868	4·879	4·889	1	2	3	4	5	6	7	8	9
24	4·899	4·909	4·919	4·930	4·940	4·950	4·960	4·970	4·980	4·990	1	2	3	4	5	6	7	8	9
25	5·000	5·010	5·020	5·030	5·040	5·050	5·060	5·070	5·079	5·089	1	2	3	4	5	6	7	8	9
26	5·099	5·109	5·119	5·128	5·138	5·148	5·158	5·167	5·177	5·187	1	2	3	4	5	6	7	8	9
27	5·196	5·206	5·215	5·225	5·235	5·244	5·254	5·263	5·273	5·282	1	2	3	4	5	6	7	8	9
28	5·292	5·301	5·310	5·320	5·329	5·339	5·348	5·357	5·367	5·376	1	2	3	4	5	6	7	7	8
29	5·385	5·394	5·404	5·413	5·422	5·431	5·441	5·450	5·459	5·468	1	2	3	4	5	5	6	7	8
30	5·477	5·486	5·495	5·505	5·514	5·523	5·532	5·541	5·550	5·559	1	2	3	4	4	5	6	7	8
31	5·568	5·577	5·586	5·595	5·604	5·612	5·621	5·630	5·639	5·648	1	2	3	3	4	5	6	7	8
32	5·657	5·666	5·675	5·683	5·692	5·701	5·710	5·718	5·727	5·736	1	2	3	3	4	5	6	7	8
33	5·745	5·753	5·762	5·771	5·779	5·788	5·797	5·805	5·814	5·822	1	2	3	3	4	5	6	7	8
34	5·831	5·840	5·848	5·857	5·865	5·874	5·882	5·891	5·899	5·908	1	2	3	3	4	5	6	7	8
35	5·916	5·925	5·933	5·941	5·950	5·958	5·967	5·975	5·983	5·992	1	2	2	3	4	5	6	7	8
36	6·000	6·008	6·017	6·025	6·033	6·042	6·050	6·058	6·066	6·075	1	2	2	3	4	5	6	7	7
37	6·083	6·091	6·099	6·107	6·116	6·124	6·132	6·140	6·148	6·156	1	2	2	3	4	5	6	7	7
38	6·164	6·173	6·181	6·189	6·197	6·205	6·213	6·221	6·229	6·237	1	2	2	3	4	5	6	6	7
39	6·245	6·253	6·261	6·269	6·277	6·285	6·293	6·301	6·309	6·317	1	2	2	3	4	5	6	6	7
40	6·325	6·332	6·340	6·348	6·356	6·364	6·372	6·380	6·387	6·395	1	2	2	3	4	5	6	6	7
41	6·403	6·411	6·419	6·427	6·434	6·442	6·450	6·458	6·465	6·473	1	2	2	3	4	5	5	6	7
42	6·481	6·488	6·496	6·504	6·512	6·519	6·527	6·535	6·542	6·550	1	2	2	3	4	5	5	6	7
43	6·557	6·565	6·573	6·580	6·588	5·595	6·603	6·611	6·618	6·626	1	2	2	3	4	5	5	6	7
44	6·633	6·641	6·648	6·656	6·663	6·671	6·678	6·686	6·693	6·701	1	2	2	3	4	5	5	6	7
45	6·708	6·716	6·723	6·731	6·738	6·745	6·753	6·760	7·768	6·775	1	1	2	3	4	4	5	6	7
46	6·782	6·790	6·797	6·804	6·812	6·819	6·826	6·834	6·841	6·848	1	1	2	3	4	4	5	6	7
47	6·856	6·863	6·870	6·877	6·885	6·892	6·899	6·907	6·914	6·921	1	1	2	3	4	4	5	6	7
48	6·928	6·935	6·943	6·950	6·957	6·964	6·971	6·979	6·986	6·993	1	1	2	3	4	4	5	6	6
49	7·000	7·007	7·014	7·021	7·029	7·036	7·043	7·050	7·057	7·064	1	1	2	3	4	4	5	6	6
50	7·071	7·078	7·085	7·092	7·099	7·106	7·113	7·120	7·127	7·134	1	1	2	3	4	4	5	6	6
51	7·141	7·148	7·155	7·162	7·169	7·176	7·183	7·190	7·197	7·204	1	1	2	3	4	4	5	6	6
52	7·211	7·218	7·225	7·232	7·239	7·246	7·253	7·259	7·266	7·273	1	1	2	3	3	4	5	6	6
53	7·280	7·287	7·294	7·301	7·308	7·314	7·321	7·328	7·335	7·342	1	1	2	3	3	4	5	5	6
54	7·348	7·355	7·362	7·369	7·376	7·382	7·389	7·396	7·403	7·409	1	1	2	3	3	4	5	5	6

SQUARE ROOTS. From 10 to 100—*continued*

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
55	7·416	7·423	7·430	7·436	7·443	7·450	7·457	7·463	7·470	7·477	1	1	2	3	3	4	5	5	6
56	7·483	7·490	7·497	7·503	7·510	7·517	7·523	7·530	7·537	7·543	1	1	2	3	3	4	5	5	6
57	7·550	7·556	7·563	7·570	7·576	7·583	7·589	7·596	7·603	7·609	1	1	2	3	3	4	5	5	6
58	7·616	7·622	7·629	7·635	7·642	7·649	7·655	7·662	7·668	7·675	1	1	2	3	3	4	5	5	6
59	7·681	7·688	7·694	7·701	7·707	7·714	7·720	7·727	7·733	7·740	1	1	2	3	3	4	4	5	6
60	7·746	7·752	7·759	7·765	7·772	7·778	7·785	7·791	7·797	7·804	1	1	2	3	3	4	4	5	6
61	7·810	7·817	7·823	7·829	7·836	7·842	7·849	7·855	7·861	7·868	1	1	2	3	3	4	4	5	6
62	7·874	7·880	7·887	7·893	7·899	7·906	7·912	7·918	7·925	7·931	1	1	2	3	3	4	4	5	6
63	7·937	7·944	7·950	7·956	7·962	7·969	7·975	7·981	7·987	7·994	1	1	2	3	3	4	4	5	6
64	8·000	8·006	8·012	8·019	8·025	8·031	8·037	8·044	8·050	8·056	1	1	2	2	3	4	4	5	6
65	8·062	8·068	8·075	8·081	8·087	8·093	8·099	8·106	8·112	8·118	1	1	2	2	3	4	4	5	6
66	8·124	8·130	8·136	8·142	8·149	8·155	8·161	8·167	8·173	8·179	1	1	2	2	3	4	4	5	5
67	8·185	8·191	8·198	8·204	8·210	8·216	8·222	8·228	8·234	8·240	1	1	2	2	3	4	4	5	5
68	8·246	8·252	8·258	8·264	8·270	8·276	8·283	8·289	8·295	8·301	1	1	2	2	3	4	4	5	5
69	8·307	8·313	8·319	8·325	8·331	8·337	8·343	8·349	8·355	8·361	1	1	2	2	3	4	4	5	5
70	8·367	8·373	8·379	8·385	8·390	8·396	8·402	8·408	8·414	8·420	1	1	2	2	3	4	4	5	5
71	8·426	8·432	8·438	8·444	8·450	8·456	8·462	8·468	8·473	8·479	1	1	2	2	3	4	4	5	5
72	8·485	8·491	8·497	8·503	8·509	8·515	8·521	8·526	8·532	8·538	1	1	2	2	3	3	4	5	5
73	8·544	8·550	8·556	8·562	8·567	8·573	8·579	8·585	8·591	8·597	1	1	2	2	3	3	4	5	5
74	8·602	8·608	8·614	8·620	8·626	8·631	8·637	8·643	8·649	8·654	1	1	2	2	3	3	4	5	5
75	8·660	8·666	8·672	8·678	8·683	8·689	8·695	8·701	8·706	8·712	1	1	2	2	3	3	4	5	5
76	8·718	8·724	8·729	8·735	8·742	8·746	8·752	8·758	8·764	8·769	1	1	2	2	3	3	4	5	5
77	8·775	8·781	8·786	8·792	8·798	8·803	8·809	8·815	8·820	8·826	1	1	2	2	3	3	4	4	5
78	8·832	8·837	8·843	8·849	8·854	8·860	8·866	8·871	8·877	8·883	1	1	2	2	3	3	4	4	5
79	8·888	8·894	8·899	8·905	8·911	8·916	8·922	8·927	8·933	8·939	1	1	2	2	3	3	4	4	5
80	8·944	8·950	8·955	8·961	8·967	8·972	8·978	8·983	8·989	8·994	1	1	2	2	3	3	4	4	5
81	9·000	9·006	9·011	9·017	9·022	9·028	9·033	9·039	9·044	9·050	1	1	2	2	3	3	4	4	5
82	9·055	9·061	9·066	9·072	9·077	9·083	9·088	9·094	9·099	9·105	1	1	2	2	3	3	4	4	5
83	9·110	9·116	9·121	9·127	9·132	9·138	9·143	9·149	9·154	9·160	1	1	2	2	3	3	4	4	5
84	9·165	9·171	9·176	9·182	9·187	9·192	9·198	9·203	9·209	9·214	1	1	2	2	3	3	4	4	5
85	9·220	9·225	9·230	9·236	9·241	9·247	9·252	9·257	9·263	9·268	1	1	2	2	3	3	4	4	5
86	9·274	9·279	9·284	9·290	9·295	9·301	9·306	9·311	9·317	9·322	1	1	2	2	3	3	4	4	5
87	9·327	9·333	9·338	9·343	9·349	9·354	9·359	9·365	9·370	9·375	1	1	2	2	3	3	4	4	5
88	9·381	9·386	9·391	9·397	9·402	9·407	9·413	9·418	9·423	9·429	1	1	2	2	3	3	4	4	5
89	9·434	9·439	9·445	9·450	9·455	9·460	9·466	9·471	9·476	9·482	1	1	2	2	3	3	4	4	5
90	9·487	9·492	9·497	9·503	9·508	9·513	9·518	9·524	9·529	9·534	1	1	2	2	3	3	4	4	5
91	9·539	9·545	9·550	9·555	9·560	9·566	9·571	9·576	9·581	9·586	1	1	2	2	3	3	4	4	5
92	9·592	9·597	9·602	9·607	9·612	9·618	9·623	9·628	9·633	9·638	1	1	2	2	3	3	4	4	5
93	9·644	9·649	9·654	9·659	9·664	9·670	9·675	9·680	9·685	9·690	1	1	2	2	3	3	4	4	5
94	9·695	9·701	9·706	9·711	9·716	9·721	9·726	9·731	9·737	9·742	1	1	2	2	3	3	4	4	5
95	9·747	9·752	9·757	9·762	9·767	9·772	9·778	9·783	9·788	9·793	1	1	2	2	3	3	4	4	5
96	9·798	9·803	9·808	9·813	9·818	9·823	9·829	9·834	9·839	9·844	1	1	2	2	3	3	4	4	5
97	9·849	9·854	9·859	9·864	9·869	9·874	9·879	9·884	9·889	9·894	1	1	1	2	3	3	4	4	5
98	9·899	9·905	9·910	9·915	9·920	9·925	9·930	9·935	9·940	9·945	0	1	1	2	2	3	3	4	4
99	9·950	9·955	9·960	9·965	9·970	9·975	9·980	9·985	9·990	9·995	0	1	1	2	2	3	3	4	4

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